ENGINEERING ANALYSIS OF MUNICIPAL WATER DEMAND AND SUPPLY FOR A FAST GROWING STATE CAPITAL.

A CASE STUDY OF ADO-EKITI, EKITI STATE.

BY

AGBEYO, OLABISI A.

MATRIC NO CVE/96/8417

THESIS IN THE DEPARTMENT OF CIVIL ENGINEERING SUBMITTED
THE SCHOOL OF ENGINEERING AND ENGINEERING TECHNOLOGY,
FOR THE AWARD OF MASTERS DEGREE IN CIVIL ENGINEERING
ATER RESOURCES AND ENVIRONMENTAL ENGINEERING OPTION)

FEDERAL UNIVERSITY OF TECHNOLOGY,
AKURE, NIGERIA.

NOVEMBER, 2004.

DECLARATION

I, Olabisi Ayoola.Agbeyo declare that this thesis was prepared entirely by me under the supervision of Dr. A.M Oguntuase of Federal University of Technology, Akure. The thesis has not been presented, either wholly, or partly, for any degree elsewhere before.

All sources of information contracted have been duly acknowledged.

O.A Agbeyo

CERTIFICATION

I hereby certify that this project was carried out by AGBEYO OLABISI (MRS) of the Department of Civil Engineering, School of Engineering Technology, Federal University of Technology under my supervision.

Omo Oguntuase

SUPERVISOR 8/12/04

DR. A.M Oguntuase

DEDICATION

This project is dedicated to the Almighty God who makes all things possible and to my entire family.

ACKNOWLEDGEMENTS

This thesis has been successfully written by the special grace of God, and the unflinching support and cooperation of a vast number of people too numerous to mention. I gratefully acknowledge all those who contributed to my success story in this master research.

My appreciation goes to my supervisor Dr. A.M Oguntuase and Dr. J.O Babatola for their support thorough supervision and co-operation.

I can not but remember the support and contribution given by Dr. A.D Adeduro of CAY-TOLA Engineering services. I also acknowledge the interest and support of some colleagues at Benin –Owena River Basin Authority and Ekiti State Water Corporation now State Ministry of Water Resources.

I am indeed very grateful to Prof Ola and Dr. Alatise both of Federal University of Technology, Akure who have assisted in one way or the other.

I am most grateful to my darling husband, daddy, mummy and children for their financial, *moral and spiritual support* as well as words of encouragement. You are all well appreciated.

I also acknowledge the support of the management of the Ekiti State Water Corporation for releasing me for this Master programme

To crown it all, I return all praises, honour and adoration unto God who has allowed my dreams in life to come to fulfillment. Thank you God.

Agbeyo, Olabisi Ayoola

2004.

ABSTRACT

Ado-Ekiti the capital city of Ekiti State is being faced by the problem of inadequate water supply due to reasons ranging from socio-economic to technical problems.

This research work evaluated the possible causes of inadequate water supply in this urban center as a result of increased influx of people, socio-economical growth and industrial growth.

The projected population plus the present supply and projected water demand were analyzed to determine the necessary quantity required and the future deficit needs to be taken care of. Also, the geological formation of this area was studied to obtain the proportion of the ground water that can serve as additional source of supply.

It was realized that the region was dominated by massive charnockite spread and little meta sedimentary rock of the quartize and fractured granitic type. This charnockite does not permit groundwater development hence the limitation to the usage of groundwater.

In this work, surface water is seen as the only dependable and reliable source of water in this region. Analysis of the available data on the nearest existing schemes established that about 60% of the production from Little Osse in Egbe can be used to augment the present supply. It is evident as well that the supply from Ero's end must remain and be steady. Also, Ureje must be operating at its fullest production capacity in conjunction with the supplies from these complementary schemes before the problem of water shortage in this region can be alleviated.

The aged pipe networks are to be replaced to minimize waste and provide better services. There is also need to embark upon extension work to the newly developed area to promote industrial and socio-economic growth.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER ONE

INTRODUCTION

1.1 General

The main sources of water for available use are surface water i.e. streams, rivers, springs, ponds, lakes and groundwater i.e. boreholes and hand- dug wells. These two major sources are replenished through precipitation. Therefore, precipitation is directly or indirectly harnessed for use. Usually before consumption, water from either sources is purified with approved chemicals to remove the physical, inorganic or organic contaminants that could affect human health.

Many factors are considered in harnessing any source of water. These include the population to be provided with adequate portable water, the available quantity of water that can be harnessed from the source, the pollution level and the probable cost of treatment including the cost of the construction of the treatment facilities required to make the water fit for consumption. After analyzing these factors together, the most economical source can then be developed.

There are situation in which, after some years, the quantity of water available for harnessing become insufficient probably due to urban drift, increased population or general increase in standard of living. In that regard, the need for either expansion of existing facilities is considered or other sources explored for additional abstraction.

Ekiti State (Fig1.1) was created in 1996, carved out of the erstwhile Ondo State, by the Military Government of Nigeria. Ado –Ekiti (Fig 1.2) the capital city could not be left out of the problems of severe water supply inadequacy. The town has a land area of approximately 128km^2 and has experienced an increased influx of people upon the creation of the State.

As expected, the existing water supply from the main water source Ureje headworks within the town, has become insufficient. It is clear that any State with an eye on development cannot ignore the quantitative and qualitative aspects of its water

MAP OF EKITI STATE

SCALE:-1:1.5 MILLION APPROX

FIG. 7.7 Map of Ekiti state

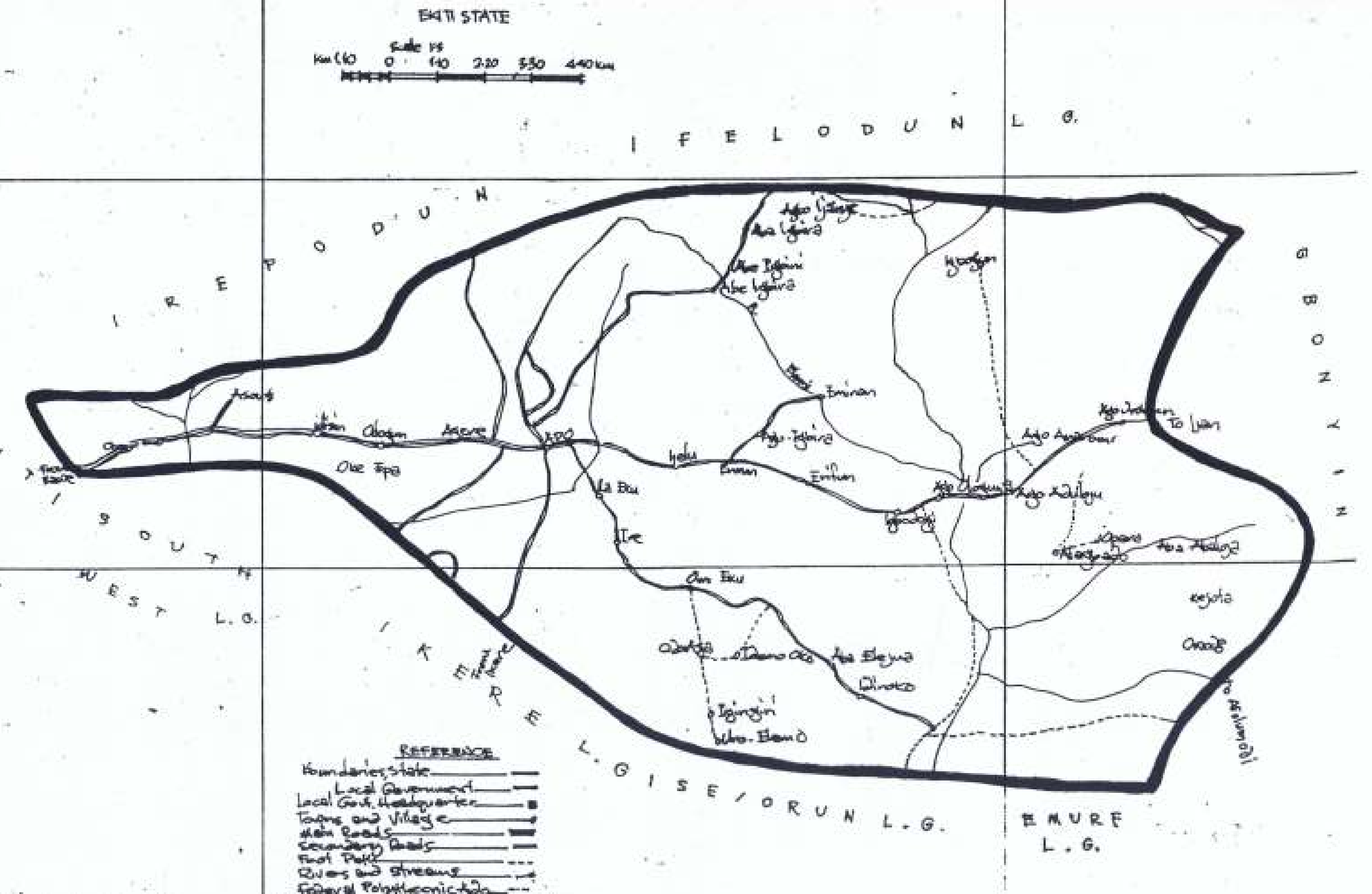


Fig 1.2 Map of Ado Ekiti

Supply. Thus the need to study the water situation in this town and its environs.

1.2 Present Situation

According to Ekiti State Water Corporation, the State's Water Agency, $4930m^3$ is produced daily by Ureje headworks and an additional quantity of $8000m^3$/day from Ero Dam at Ikun-Ekiti boosts the supply to Ado Ekiti. Fig 1.3 indicates how the supplies from both ends are distributed through various types and sizes of pipes. Since 1996 the supply from Ero- Dam has been unsteady, and sometimes not forthcoming due to erratic power supply to the headworks at Ikun. Rehabilitation works by the State Government are in progress. The inadequate supply necessitates the rotational supply from Ureje headworks.

Due to the shortage of water supply in the city, more than 70% of the people depend totally on wells, springs, rain water as an alternative supply, despite the fact that the wells in the area are not highly productive.

According to Adeduro and Fadipe (1992), this region has been classified as being poor in groundwater potentials because of its geological formation. The region is generally dominated by massive charnockite, covering more than 60% of the total land area with highly fractured granitic rocks in some places. It is also said that the region has a very thick overburden of clayey soil materials.

According to Ibunkun (1987), the hand-dug wells which fully penetrate the overburden are characterized by small water columns (<1m) especially when it is far from a stream but those dug near streams have thicker water columns. Despite the above, there are a few good productive hand dug wells and boreholes scattered all over the city especially in geological conducive areas. These few wells are productive throughout the year.

Ado-Ekiti region is a catchment area of River Ogbesse and its tributaries (Ebesemiju 1993). There is high rainstorm in this region but because of the region's topographic terrain, the rainstorm is drained fast to the disadvantage of the region.

During rainy season, the people harvest rainwater to store (though sometimes in an

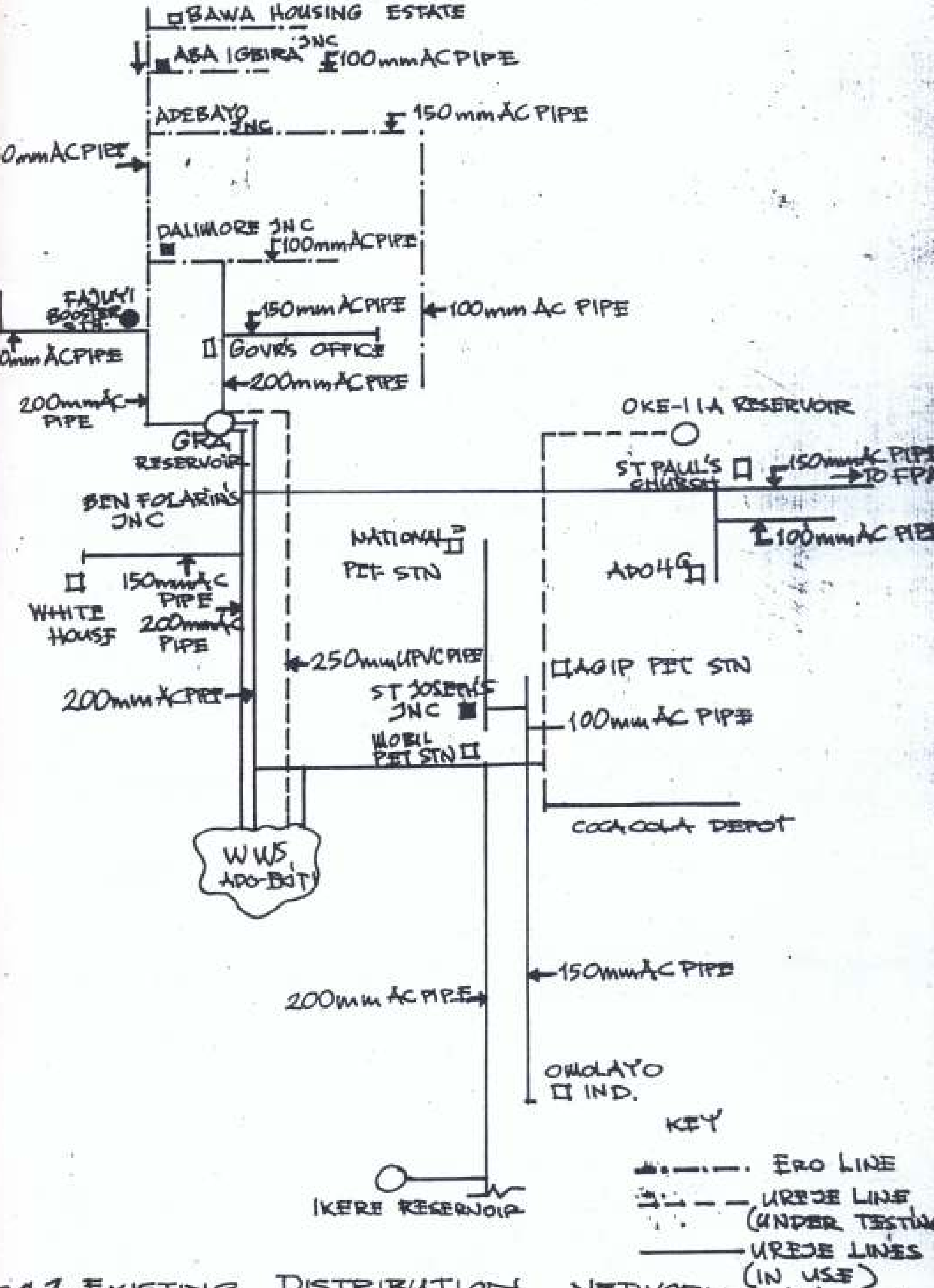


FIG.1.3 EXISTING DISTRIBUTION NETWORK IN ADO EKITI

unhygienic manner) for their domestic use. The stress in searching for water during this period of 6 to 7 months is reduced. The excess water harnessed from the rainstorm also reduces the pressure on the potable water supply

During the period of inadequacy mostly between December and March there is usually a very high water deficiency in the region. The people then resort to high water economy, that is, optimal use of available quantity of water for maximum benefit.

1.3 Objective of the Study

The general objective of this study is to determine the adequacy of conventional water supply to Ado Ekiti and to examine other potential sources that can be harnessed to improve both the present and future water requirements of fast growing town.

The specific objectives of the study are:

(i) Identification of the causes of inadequate water supply from the Water Agency.

(ii) Determine the specific technical ways and methods of alleviating the problems caused by inadequate supply.

(iii) Projection of the future water requirement and the means to meet up with it.

(iv) Determination of suitability of Ogbesse River at Aduloju as a possible source of water supply to Ado-Ekiti through examination of water quality and hydrological data.

1.4 Justification

This study is necessary because it will provide technical information on the present water supply situation and the water resources potentials of Ado – Ekiti catchment area and how these potentials can be optimally utilized to meet both the present and future water requirement.

It will also provide information on the possible quantities of water that can be used to augment the present supply in Ado- Ekiti from Ero, Little Osse without interrupting the services of these schemes to other areas they are designed to serve.

The study is also essential because even if Ureje's production capacity is expanded to be doubled, this will still not be able to cope with the growing rate of this city, hence the need to source for additional supply from other areas.

CHAPTER TWO

LITERATURE REVIEW

The rapid human development and associated activities in different fields of human endeavours created urbanization which soon make water supply sources inadequate in urban settlements, and began the series of large-scale water developments. The ever increasing world population and demands for water supply to satisfy domestic, industrial and commercial purposes soon over stressed such new developments, hence the need further for, search for more convenient and economic water sources, control and supply to meet ever increasing demands.

Therefore, determination of quantities and rates of growth contribute to an understanding of urbanization. The propensity to classify and categorize urban areas is enhanced by access to simple and reliable data.

The importance of the resources of a country, in terms of their potential for exploitation or natural development, inevitably has had an impact on the extent and character of urbanization.

Urban system may mean the city viewed as a large geographical setting. The city encompasses many complex elements, functions, and activities, which are interrelated in several ways. The city also exists and functions within its surroundings, its environment and its settings. It has geographic and physical, aspects such as rivers, flood plains and watershed, topography, climate and land. The setting also has social ,and economic aspects involving the region and neighbouring states. Webb (1998) states that cities are complex systems requiring special methods of prediction and management. The system needs to be thoroughly studied, so as to make decisions affecting it on the basis of available information.

For effective management of an urban centre, most especially the water sector, a good understanding of the population growth is required.

A population projection is a professional and technical undertaking that is affected by a number of factors. The size of the population unit varies directly with the accuracy of the population. The larger the unit the more likely the projection will approximate the subsequent fact because of the cancellations of complication factors and compensating errors. Secondly, obtaining accurate data is hampered by the relative unreliability of census data from newly developing countries. Thirdly, the projections of populace vary with the assumption made in the process including the rate at which population is expected to increase or decrease due to political situation, industrialization and similar factors.

The World Bank report in 2002, revealed that in spite of great efforts spanning several decades, about 1–2 billion people in the developing countries lack access to safe drinking water supply. By the year 2050 an estimated 65% of the world population will live in areas of water shortage (Milburn,1996). Newer water sources to keep the pace with population growth is slowing down and if this trend continues about 25%-40% of population will face shortage of fresh water (Knight,1998).

In terms of quality, the World Bank report states that in the 1980s, more than 1.6 billion people have access to water of reasonable quality but sanitation services expanded substantially. Data from the WHO indicated that at least 170 million people in urban and 855 million in rural areas still lack a source of potable water. Despite large investments in water and sanitation in the 1980s and 1990s, the number of people without access to basic water and sanitation services in urban and semi-urban areas continue to increase. That of Ado Ekiti, Nigeria is not an exception.

IRC international water and sanitation (2002), states that in all quality cultures water has an essential role in maintaining health and enhancing the quality of life by the availability of ample supplies of safe drinking water and by the provision of sufficient water to satisfy the legitimate requirements of agriculture and industry. It can also affect both the social and economic lives of the community. Most investors will not like to invest where this essential amenity is lacking.

Reductions in water borne disease occurrences are attributable to improvements in the quality or availability of water. It is worth mentioning that intermittent service jeopardizes the support expected of many water supply projects and hinders performance of may such dependent industries.

WHO reported that the poor suffer disproportionately when water supply is unreliable. Weather households, and industrial firms can install private wells though at additional cost to their economy. These options are beyond the reach of poor consumers. Inadequate and intermittent service can cause epidemic and outbreak or cholera as well as other water related diseases.

In the Urban sector the very poorest people generally lose out completely because they don't have access to piped-in water (Postel,1999). Some of them spend reasonable part of their income paying for water from vendors. So there's a huge inequity here, society subsidizes the piped-in water for urbanites, but it's the poorest people who don't have any piped-in water at all who end up spending a huge share of their income for water to avoid being sick

Postel (1998) reported that in a situation of water shortage for example, causing food prices to increase, this might lead to social instability. She mentioned that over the last few years when governments, for one reason or the other, have had to remove subsides for food, we've seen riots in the streets in a number of countries. So anytime there's an increase in food prices in a poor country, you risk social instability. Postel (1999) cited several countries like Indonesia and Jordan where these have happened.

The infrastructure challenge with water supply according to Postel (1999) is huge and very much of it is still unmet, especially in the rapidly growing mega cities. We've got so many people in a concentrated area, and finding enough water within a reasonable distance of the city to supply many people is very difficult. Many of the mega cities as stated by Postel are having a difficult time with water supply.

The supply of water and sanitation services to growing urban agglomerations has already grown to a large scale in the world (Milburn, 1996). Solution to this problem depends on research and introduction of innovative technologies in water sector and on long-term national planning and development using technical, behavioural and legislative means.

Operations and Evaluation department of World Bank mentioned that to provide a continuous safe water supply service calls for ample and reliable water source and adequate capacity for treatment, transmission and distribution. This will require properly functioning pumps, reservoirs, and networks. It further reported that the way these facilities are operated and maintained could greatly affect the health of the population, the quality of the environment, the benefits to the poor and the resource available for investment in expansion.

The good operation and maintenance could enhance the quality of services and extend the useful lives of facilities. This also depends on better funding of the water utilities, and having the resources available for investment in new services. The department advises that to maximize the costs of operating a water-supply system, competent management of capital and current expenditures, assets and liabilities are just as important as preventing losses of water from the system. Adequate cost recovery ensures that enough funds are available to pay for operation, maintenance and debt service.

The cost imposed on economies by poorly run and maintained water supply although not well documented according to the World Bank but is clearly very large. There is ample evidence of poor quality water, unnecessary sporadic service and large volumes of unaccounted for water as per World Bank findings.

The World Bank reported that from its routine reviews on the operation and maintenance performance of its borrowers, many water utilities that the Bank has supported their projects lack serious maintenance, which was already apparent during project preparation and implementation. Its root cause was usually lack of funds, which led to shortages of managers, qualified to organize O & M, shortages of skilled personnel and shortages of spare parts.

From the report on sanitation on communities living in the peri-urban centers of Malawi in South Africa some methods i.e. demonstration schemes of the Urban communal water part project in 1981, training, hygiene education and sanitation exercise were methods developed to improve planning and implementation supplies within communities. Malawi then was still in an early stage of urbanization with 11% of the total population living in the urban centres. It was also estimated then that up to 60% of the urban population lived in the fringes of the urban centres.

Also, in this report was that before 1980, there was no regular water supply services in these communities. Some people got their water from various unreliable, contaminated open water source, others got their water from vendors at very high rate. Traditional Housing Areas often lack the most basic facilities normally provided to urban communities. Among the major factors contributing to the sustainability of the project was that the communities in the piped water supply demonstration schemes play a bigger role in the maintenance of the water supply system. These schemes had been successfully developed in nine of the urban centres in five regions of the country.

Development of new technologies and innovative total water system solutions for urban areas is needed to satisfy present human needs with respect to living standards and the present environmental goals. These future system solutions will encompasses water supply, quality-dependent water consumption, reuse of rainwater Niemczynowicz (2002).

One thing that's important in these cities is that they build an efficient infrastructure into the urban water systems from the beginning that they use the most efficient appliances and fixtures at the household level that are available.

The World Bank helps government to develop strategies for utility modernization and establish regulatory frameworks that encourage better performance and fasten investment in the sector. They revealed that because the pressure to provide services to more people is intense in the water supply sector, new facilities receive higher priority in terms of budgets and staffing than operation and maintenance. In a financial crisis, operation and maintenance budgets are the first to be cut, with consequent deterioration of pipes, machinery and service.

According to a text (the National Handbook of Recommended Methods for Water Data Acquisition on Public water supply), many cities or urban cities are mandating the use of water saving devices, raising water rates, and implementing restrictions on water use because of extended droughts or the need to keep demand within the safe yield of the system. The Greater Boston Metropolitan Area, USA dramatically increased the reliability of their water system through conservation. The area served by the Massachusetts Water Authority experienced nearly a 20% decline in water use from 1988 to 1992, as a result of leak detection programs, domestic conservation programs featuring public education and retrofit low-flow fixtures, conservation consulting services provided to industrial and commercial users, and rate increases for water supply. The text also states a detailed water demand analysis of future water use in the city of Boston showing that a combination of charges caused by new regulations will further result in substantive reduction in water demand over the next 25 years or so despite increased population.

Operation Evaluation Department of the WHO shows that day-to-day management of water utilities is often complicated by problems at the national level; inadequate or ambiguous legislation and poor allocation of fund.

Niemczynowicz (2002) states that the majority of developing countries in spite of possible future economical development will not copy water and sanitation programme of the developed world. It is also clear from this report that in order to alleviate problems associated with water supply, it is necessary to develop methods for multiple and/or quality dependent water use in households and introduce more efficient economical incentives to save water. Quoting Niemczynowicz (2002) "it is clear that some countries must come back to ancient habits to collect and use storm water for non-consumptive water uses." For example, roof storm water may be used after separation of runoff for the first few minutes of the rainfall using simple mechanical devices.

According to Seattle (1995– 2000) the Central Puget Sound region has experienced rapid growth in population and development. Because of these the water supplies forum came into being in 1999 and for the first time, water utilities in the Central Puget Sound area are jointly assessing long term municipal and industrial water demands, existing supplies and potential shortfalls. The write up states that the group will help identify where water supply demand shortfalls may occur by the year 2020, as well as an array of potential local, sub regional and regional solutions that could alleviate shortfalls. They will also include assessment of regional resources and corresponding infrastructure, as well as future conservation and re- use options.

The Arava Valley provide a unique opportunity for exploring community involvement in water conservation and policy in the domestic arena. Communities on both sides of the border share common ground water sources for domestic use, but differ in household and water supply infrastructure. The report states that National Policy and research on alleviating water scarcity have emphasized increasing supply in the face of rising demand rather than on the more obvious solution of conservation programs for existing supplies.

A water supply utility is successful if in association with continuous service and good quality water, there is a low rate of unaccounted for water (ufw). Rates of ufw vary from system to system but evaluation findings, according to the World Bank confirm that in most water supply entities they are unduly high.

Reformed water utilities and attaching private investment is difficult (World Bank, 2002). Politically sensitive tariffs, limited scope for competition, slow asset turnover requiring long-term debt finance and a daunting mix of currency, information country and sub-sovereign risks all require careful handling if private participation is to succeed. Thus, it often calls for a step-wise privatization process, first transforming operation and maintenance (O & M) responsibility to a private firm under a lease or management contract with public financing of investment, then moving up to a concession as information confidence and the regulatory environment improve.

For the private providers of services, the World Bank reported that the desire to raise net earnings normally provides enough motivation to maximize the use of capacity along with revenue and keep expenditures at a minimum.

The World Bank report stressed that in very poor countries, random systems with extremely low tariffs may take considerable time before they can be made commercially viable, as tariffs hike must be sequenced with service improvement.

Public utilities often have difficulty getting approval for increasing their charges to levels that are financially and economically adequate. Sometimes this for political reasons. Higher charges must be justified not only to the parent entity but also to consumers. Public relations campaigns can be helpful here, but quality service is often crucial to securing consumers' acceptance of increase.

According to Postel (1999) report the wastewater is still being released to the environment untreated in these mega cities.

CLIMAS (2003) on urban water study examines the impacts of climate variability and population growth on water supply and demand in five urban areas of Arizona.

The urban water sensitivity analysis was to illustrate the importance of factoring climatic variability into assessments and projections of water supply and demand variability. The objective of this report is to encourage the use of climate information, including historical and paleo data as well as forecasts, in water resource planning and decision making at time scales ranging from seasonal to annual, inter-annual, and multide cadal.

According to CLIMAS (2003) water sensitivity analysis was carried out in 5 urban areas of Arizona and the result showed what parentage of an area's water supply would have to be mined from groundwater reserves under the different climatic, water use, and population growth scenarios. Also, the relative sustainability of water used in each situation was evaluated and stated in the report.

In the Middle East, severely limited water resources and rapid population growth pose a continuous risk to the availability of high-quality water for personal use.

Lipchin (1999) estimated the annual precipitation in the Arava valley, which was through Southern Israel and Jordan as only 4mm, compared with 31mm in Los Angeles. The research has revealed that Israel's consumption of fresh water has exceeded sustainable yields since the mid- 1970s, while Jordan's extraction of water from highland aquifers is almost 80 percent above the annual recharge rate. As available surface water becomes over-exploited, groundwater is fast becoming the most important source of fresh water for domestic use in both countries. The research established that all available fresh water in the Arava Valley comes from groundwater primarily from non-renewable aquifers.

Urban Water (2002) places emphasis on defining the practical outcomes of sustainable development and on documenting and analyzing the mutual interrelationships and interactions between the individual water systems and urban water bodies (including groundwater). In the Bandung area, groundwater abstraction had led to considerable lowering of the groundwater table after about 1980 to as much as 20m compared to that in 1900 (Haryadi & Schrudit 2001). The model calculations according to the report show that new production wells should not be located in Bandung, but in the eastern part of the Bandung basin.

According to Ministry of Information Fiji (2002), availability of adequate water supply is essential for maintaining safe household sanitation facilities. As for ground water quantity, as water pumping increases to meet water demand, it can exceed the aquifers rates of replenishment thereby resulting in considerable lowering of water table. Examples are many urban aquifers, which show long-term decline in water table. With excessive extraction comes a variety of other undesirable effects such as:

(i) Increased pumping cost.
(ii) Changes in hydraulic pressure and underground flow direction (in coastal areas this can result in intrusion of sea water)
(iii) Excessive water drawn up from deeper geological formations and
(iv) Poor quality water from polluted shallow aquifers leaching down wards.

Severe depletion of groundwater resources is often compounded by a serious deterioration in its quality Chilton (2002).

Problems of land subsidence can also follow rapid depletion of aquifers. This can affect both upland and lowland cities. Land subsidence not only damages individual buildings and roads, but also underground piped services, further increasing water depletion and contamination. leakages from water mains, sewers, ruptured oil pipelines and underground tanks can add to shortages of water as well as groundwater pollution. The rivers flowing through these areas are very, very polluted. In order words, water quality is deteriorating as a result of industrial and municipal wastewater contamination. It's a sort of double warning there is a supply problem to begin with, and then one ends polluting some of the surplus available. Water quality and water quantity problems go hand in-hand in these areas.

CHAPTER THREE

RESEARCH METHODOLOGY

Ado – Ekiti was the divisional headquarters of Ekiti Division in the Western Region. It is presently the capital city of Ekiti State. The state is one of the six created by the Federal Government of Nigeria in October 1996.

3.1 Data Collection

Data were colleted through the field surveys. The data collected were technical data relating to the major water schemes and headworks, designed production capacities and pumping records, data relating supplies to consumers, and identified boreholes locations. Other data collected were the meterological data of the study area, to assess the quantity of rainwater that may be available for supplementary domestic use. The hydrological data of River Ogbese, which is the headwater of many tributaries, and the geological data on the formation of this region were all collected along with others which are relevant to this research work. These data were collected through.

(1) Appraisal of existing water schemes through units and examination of designs and operational documents

(2) Field measurement and collection of samples for analysis

(3) Oral interviews

(4) Visits to other relevant offices for necessary operational document.

3.2 Technical performance evaluation

Performance evaluation was carried out on the selected headworks. Available documents relating to operation, repairs and maintenance were studied and data collected.

Types of questions that come to mind include:

(i) Are the selected relevant headworks giving satisfactory services and why?

(ii) Is it possible to carry out any improvement work on the existing scheme for an improved service and how?

(iii) Does any system components need any replacement or repairs?

(iv) How are the consumers being fed?

(v) Is the water reaching everywhere and is the pumping regular?

(vi) Is an identified borehole productive?

(vii) Wells around an area, do they dry up when and why?

Details of the production of the intending complementary schemes were collected from the headquarters of the water Agency.

3.3 Field Measurements and surveys

The following measurement were carried out in the course of this study

(i) Water was colleted from R.Ogbese for quality analysis

(ii) Distance and elevations along Aisegba, Ijan, Ado route were determined for possible interconnection/looping.

Other field measurement carried out in this work include:

(i) Public dependence on different sources of water

(ii) Identifying successful functioning boreholes

(iii) Areas covered by network.

(iv) Visit to new area just opened up without any extension lines. i.e. the rate of expansion does not commensurate to rate of extension.

3.4 Data Analysis

In conducting comprehensive appraisal of existing water schemes, records of monthly production of some of the schemes were collected and compared with the designed production capacity to determine the efficiency of the schemes.

From the data, the constraints hindering water production were identified. Accessibility of urban dwellers to good water supply was examined using the existing supply records.

3.5 Environmental Setting

3.5.1 Location

Ekiti State is on the Southwestern part of Nigeria (Fig 1.1). The state capital, Ado - Ekiti with a land area of about 128 square kilometers is situated between latitudes 7° 32' and 7° 40'. The Longitudes are 5° 061 and 5° 25'. To the north of Ado Ekiti is Ilorin to the south is Akure, to the east is Ikare and to the west is Ijebu –Ijesa. On becoming the State capital there is increased influx of people as well as urbanization to meet up the new status. There is also need for improvement on the present social amenities to meet up with this development.

3.5.2 Climate

The climate of Ado-Ekiti like the rest of the state and country is influenced by the rain bearing south-west trade (monsoon) wind and the North-East dry (harmmatan). wind from the Sahara desert. Four seasons are identifiable.

- The long raining season – March/April to July
- The short dry season or August break - August
- The short raining season – September to November
- The long dry season – mid November to March

Ado-Ekiti region falls within the seasonally – wet tropical savanna climatic belt with a uniformly high mean monthly temperature of about 25°C The amount of moisture in an atmospheric column is called precipitable water. The formation of precipitation required the lifting of an air mass in the atmosphere so that it cools, water condenses from the vapor to the liquid state to form rain. If the temperature is below the freezing point, then ice crystals are formed instead. In this region precipitation is usually rain and the mean annual rainfall is 1683mm. These weather conditions are prevalent especially during the long dry season and there is very little change in daily or seasonal temperature.

3.5.3 Relief and Drainage

The land in Ado Ekiti rises northwards and westwards from 335m in southeast, and attains a maximum elevation of about 750meters in the southwest near Adugboku according to Ebisemiju (1993). The relative relief, that is, the difference between the highest and lowest points in the region therefore is 395m. High elevations and relative relief, however, according to Ebisemiju (1993), are encountered only in the west, southwest and north, as about 55% of the region (the central and eastern part) lies at elevations between 335m and 400m (relatives reliefs of only 65m). Over much of the area, therefore, has a low relief.

The charnockitic and granitic rock which are cogenetic magmatic suite within the basement rocks in southwestern Nigeria are the most prominent rocks in the Ado Ekiti area. They determine the drainage pattern and the hydrogeological conditions of the area (Fadipe and Adeduro, 1992).

Ado Ekiti region is drained by the headwater tributaries of River Ogbese which takes its source from the region (Ebisemiju 1993). The principal tributary streams of River Ogbese in the region are the Airi, Afin, Omosuo and Elemi (Fig 3.1). Although some of the rivers and streams in the region exhibit localized structural and topographical control on their courses, the overall drainage pattern in Ado Ekiti region is dendritics. This is attributable to the fact that the minor streams develop on the saprolites of the deeply weathered rocks.

3.5.4 Vegetation

The region is located according to Adeniyi (1993) in the low land rainforest zone. Forests in general are characterized by abundance of tree species e.g. timber, firewood, drugs, ornamentals and spices. Apart from the beauty and amazing diversity of forests, they also provide habitats for wildlife.

Adeniyi (1993) observed that centuries of human activities have resulted in the replacement of the natural lowland rainforest vegetation with derived savanna in inselbergs and residual hills, and with secondary forests, thicker, fallows, herbaceous vegetation, cocoa plantation and farmlands on the lowlands.

3.5.5 Geology and Hydrogeology

The geology of Ado Ekiti region is a part of the basement complex rocks of south-

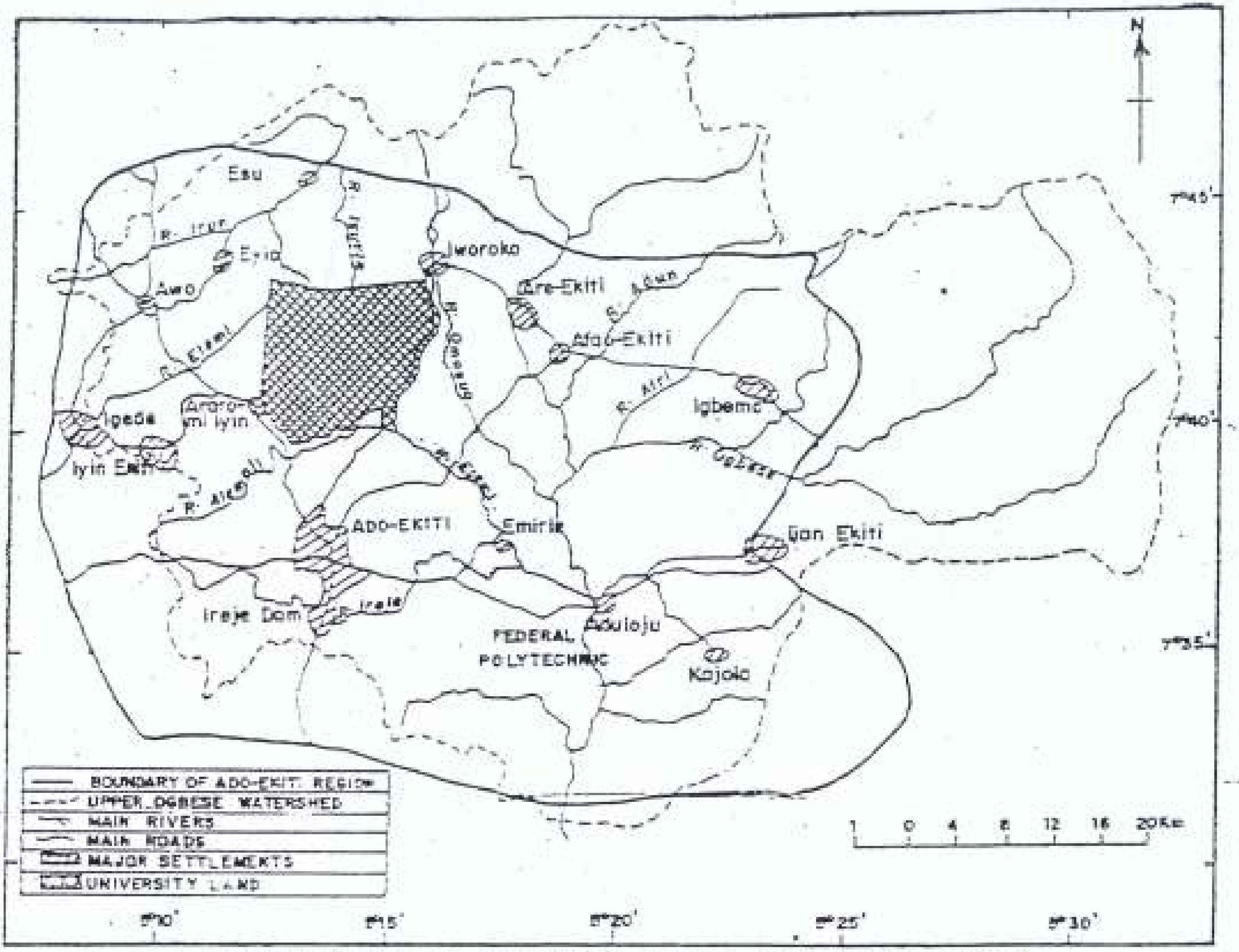


FIG. 3.1 Regional setting of Ado-Ekiti Region in the Upper Ogbese River Basin

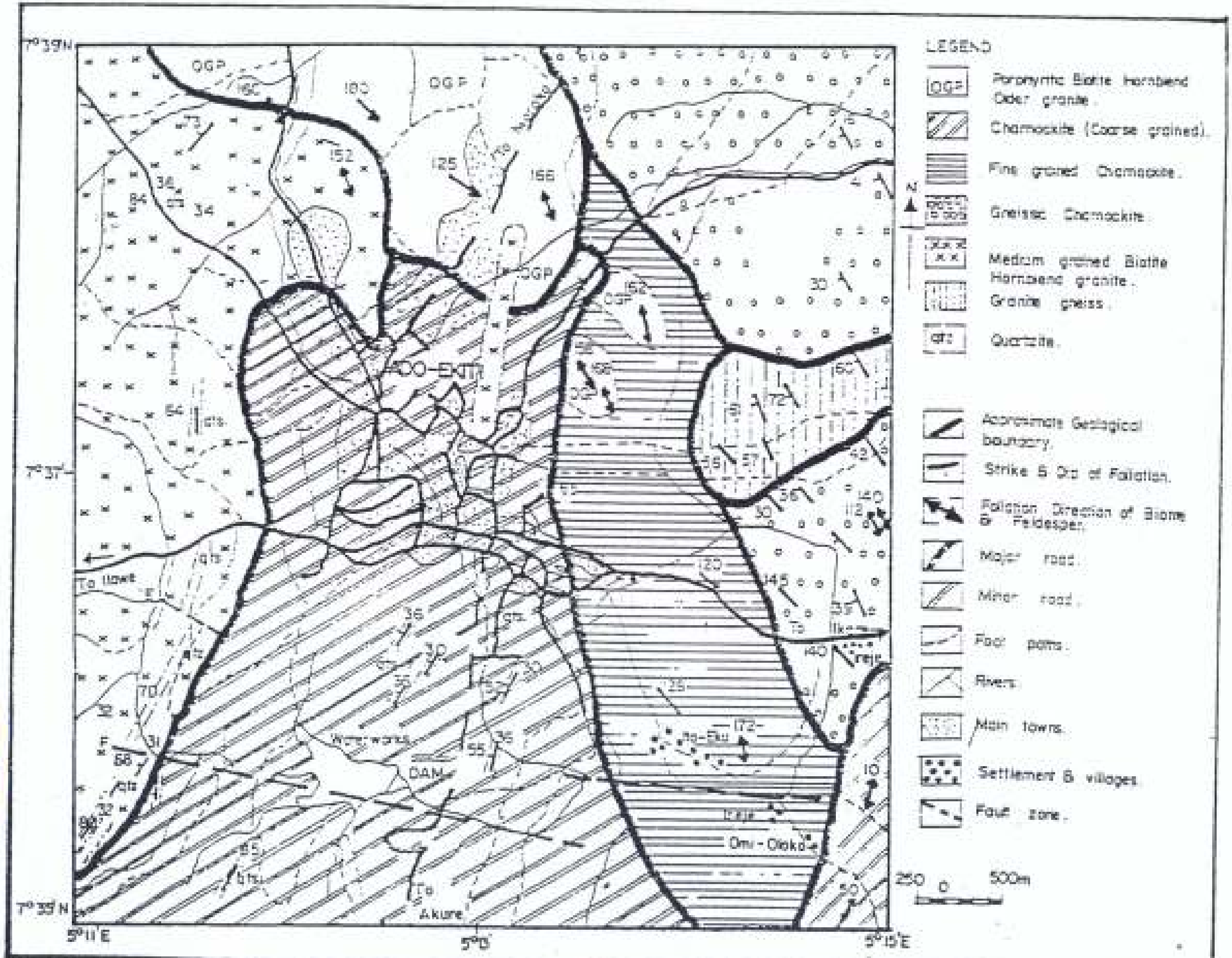


FIG. 3.2 Geological Map of Ado-Ekiti Area

western Nigeria (Rahaman, 1991). The geological formation is dominated by massive charnockite and granite rocks (Figure3.2). There are also metasedimentary rocks such as quartzite's forming interceptions in the grantic rocks (Olanrewaju, (1981) Fadipe and Adeduro, 1992).

The hydrogeology of the areas is controlled by the nature of weathered formation and depth. The charnockite region is usually weathered to clayed soil formation which are hydrogeologically unsuitable for groundwater development due to their poor quality aquifer condition. Ground water is held in appreciable quantity in granitic and weathered quartzite. (Adeduro, 1992; Fadipe and Adeduro, 1992). Generally groundwater potential yield is poor in the region but faulted and deeply weather granite and quartzite zones have good aquifers.

3.6 History of Water Supply in Ado-Ekiti

The town has numerous springs and streams scattered all over the town out of which about 15 were in use for direct consumption. The popular ones in use then were Olotoro spring situated along a slope towards Federal Housing at Oke Ila. This spring was serving the whole of Oke Ila, Oke Iyinmi and Ajibade communities. The Orojuda spring is at Aremu. This was serving the whole of Aremu community, part of Oke Isha, Ereguru, Ojumose down to Igbehin and part of Irona communities. Ayisola springs were at Odo Ado, Olokemeji and the other along Igirigiri road. They were serving the people around Odo Ado, Idemo, Idolofin and Ojido. Ofin River along Iyin was serving the settlement along Basiri area. Olokuta and Olumuroko springs situated along Ajilosun area were being consumed by people at Ijigbo, part of the community along Mathew Street of and Odo Ado. Omi olori spring the source of which was from Olota hill was mainly for a section of the people situated at Idolofin. Oloogan and Olobe springs situated along Dallimure area were being consumed by people along that area, Kajola and Oke Ese. Also the Omisanjana River was serving the people along Omisanjana area, part of Irona, the Ile Abiye area.

The town is blessed with the afore-mentioned springs, streams and river for consumption but none was being treated during the colonial period.

They were also using rain water for other purposes but not for drinking. The raw water from the thatched roof then in use would have become seriously coloured.

In the early times the peoples of Ado Ekiti depended on streams, springs and rain for domestic water supply. Later development [colonial period] saw some elites and schools storing rainwater from their roof- tops in surface and subsurface reservoirs. The rapid development in urbanization and the associated new status of the town led to a general increase in communal activities, which necessarily demand an increase in the water needs of the people.

Ureje scheme with a designed capacity of $2930m^3$ /day came into being in 1961. In 1980 its capacity was increased to $4930m^3$/day which is still the case now.

Due to its present status there has been a great increase in its population and commercial activities resulting in the expansion and high development rate of the town. The Ureje scheme is therefore unable to cope with the present water demand. Hence the inadequacy in water supply.

CHAPTER FOUR

Water Demand Studies

The water supply to Ado-Ekiti is generally on rotational basis despite that the distribution lines cover only about 30% of the town. In some areas there are extension pipeline, with no water supply.

It is against this background that an attempt is made in this chapter to estimate the present and projected water need of the different sectors in the region. But for a proper water planning, the population must be determined and projected population must be known hence the population of the region is studied.

4.1 Population and Projection

Ado-Ekiti is growing at an unsteady rate. The population in 1990 was 127,878 projected to 148300 in 1996 (Ministry of Information, Culture and Statistics).

From 1996, Ado-Ekiti has a new status of a state capital, which forced an increased influx of people hence a spontaneous increase in population.

The growth rate from 1990-1996 was 2.5%. As a result of this development, the Military Administrator's Office, Ado-Ekiti used a high variation of 6% for population projection between 1996 and 2000. The population growth rate has normalized. In the present study, a growth rate of 4.5% is assumed for 2003-2010 and 5% for period beyond that because of the envisaged improvement in commercial and industrial activities in the state. Applying Agunwamba (2000) formula: $P_f = Pl(1+k)^n$. Where P_f is the future population, P_i is the initial population, k is the growth rate and the design period, the projected population of Ado-Ekiti is estimated as in Table 4.1

Table 4.1: Population Projection of Ado-Ekiti Town.

Year	Population'000
1996	148.3
2003	201.8
2010	274.6
2015	350.5
2020	447.4
2025	571.0
2030	728.7
2040	1,187

4.2 Domestic Water Demand

The average value of domestic water consumption is 120 l/c/d for some cities in Nigeria (Agunwamba, 2000). This is applicable to Ado-Ekiti and it is therefore used to calculate the projected domestic water needs for the projected years considered.(Table 4.2)

Table 4.2 Present and Domestic Water Needs of Ado -Ekiti

Year	Domestic water need (000m^3/day)
1996	17.8
2003	24.2
2010	33.0
2015	42.1
2020	53.7
2025	68.5
2030	87.4
2040	142.4

4.3 Industrial/Commercial Water Need.

Ado-Ekiti is a fast growing city, Industries requiring water will be springing up from time to time hence the possible water need as highlighted in Table 4.3.

Table 4.3 Industrial/Commercial Water Need of Ado-Ekiti

Industry	Nos	Demand in m^3/unit output	Daily production (tonne)	Daily water requirement (m^3)
Wood industry	7	5/tonne	12	420
Paper mill	2	10/tonne		20
Textile	1	20/tonne	2.0	40
Laundries	10	20/tones	_	200
Block making	250	5	_	1250
Hotels & private restaurants	200	15	_	3000
Bakeries	50	5	_	250
Gold Room	10	5	_	50
Abattoirs	10	5	_	50
0thers	_	_	_	5500

(Source: - Field interview, 2003)

An increasing industrial and commercial activities in envisaged for the city. It is estimated that the growth rate in this sector will be about 10%. Hence its demand for water all increase correspondingly in the projected years.

4.4 Institutional and Social Water Need

The institutional water need is calculated based on the present population of students at different educational levels in the city (Table 4.4)

Table 4.4 Institutional and Social Water Requirement for Ado Ekiti

Institution	Nos	Consumption (lped)	Mean population size	Gross daily demand (m^3)
Nursery school (Private)	49	3	210	29400
Primary School	63	3	2414	450246
Secondary School	12	5	1383	82980
Technical College	1	5	800	4000
School of Nursing & Midwifery	1	10	116	1160
Polytechnic	1	10	8500	85000
University	1	12	14340	172,080
Others	-	-	-	600
				830,866

An increase of 20% in the institutional water need is included in the possible projected water need to take care of institutional expansion from time to time (Table 4.4)

4.5. Unaccounted for Water

Ready estimates of losses from pipelines construction points and taps are not usually available, but these are generally believed to be quite high. According to Agunwamba (2000), this may be taken as 10% of the total water demand. This value is considered reasonable for this study.

Also a certain quantity of water must be provided for fighting fire. The amount of water for fire fighting depends on the inflammability and intensity of heat generated by the burning material, contents and type of building (Bond 1996). The total quantity of water required may be a small fraction of the total consumption.

The amount required to extinguish a large possible fire is 200 –300m^3.

Considering all the tables on water demands i.e. on domestic, institutional and social plus industrial and commercial, then the projected total water need is calculated as in Table 4.5.

Table 4.5 Projected total water need in Ado-Ekiti (m^3/day)

Purpose	Year						
	2003	2010	2015	2020	2025	2030	2040
Domestic	24218	32957	42063	53684	68516	87445	142439
Industrial	5500	6000	6600	7260	14520	15972	17569
Institutional	830.87	997	1197	1436.4	1723.3	2068	2482
Fire Fighting	200	220	242	264	290	310	341
Sub-Total	30748.87	40174	50102	62644.4	85049.3	105795.5	162831
Unaccounted for water (10% of sub-total)	3074.89	4017.4	5010.2	6264.4	8504.9	10579.6	16283
Total Need	33823.76	44191.4	55112.2	68908.8	93554.2	116375.1	179114

4.6 Water Quantity Assessment

In this section the quantity of water that can be possibly harvested from rain, abstracted from groundwater and withdrawn from available surface water, are estimated.

The average rainfall of the study area within a period of 1991-1993 is as per Table 4.6. From this record the mean annual rainfall is 1683mm.

4.6.2 Water from Hand Dug Wells and Boreholes (Groundwater)

Groundwater is formed by rainfall which permeates into the ground through the pores of rock formation and finally reaches the underground water table and the water from streams, lakes and reservoirs which percolate through the soil to the underground water table.

Table 4.6 Average Rainfall in Ado-Ekiti (mm) 1991 – 1993

Months	1991	1992	1993
Jan.	1.2	0	0
Feb.	98.6	0	57.0
Mar.	136.0	40.8	18.8
April	273.2	107.8	84.6
May	201.2	51.1	95.1
June	163.7	237	108.6
July	463.0	265.3	131.8
August	203.6	101.7	274.1
September	200.7	347.6	No Record
October	152.6	194.6	95.9
November	Tr	25.6	84.3
December	10.4	0	21.4
Total	1904.2	1371.5	1771.6

Source: Benin-Owena River Basin Authority.

There are different types of wells, which maybe classified based on depths of the water level or the method of construction and development i.e. shallow or deep wells, hand dug or boreholes.

The groundwater potentials of Ado-Ekiti region according to Adeduro and Fadipe (1992) is dependent on the soil overburden thickness, secondary porosity due to fracturing and jointing, general topography and drainage characteristics.

Generally in this region hand dug wells, the depth of which ranges from less than 3m to 7.5m and sometimes 12m are seasonal in nature. They tend to have more yields during rainy season and less in the dry season.

As Ado-Ekiti is underlain by ancient crystalline igneous Cambrian basement complex (earth pan). these crystalline rocks are made up of granite, gabro and diorite. Also coarse grain charnockites are found in addition to ponphyrilic granites. This type of geological formation does not favour reliable ground water fracture.

Boreholes in crystalline rocks are better limited to a depth between 50m and 60m. The groundwater yield, according to a driller from WATSAN who was involved in drilling works in this area, ranges between 0.541/s to 3.541/s. This estimation is not based on pumping test done and so cannot be accepted. Also, more detailed geological works will be required to determine the actual sizes of the different aquifers available in the region, rate at which each is being recharged at different periods/season of the year and the possible maximum abstraction from time to time. These along with other engineering parameters i.e. type of soil, porosity of the soil etc. will be required before the actual volume of the available under groundwater in the region is determined hence the adoption of Table 4.7.

Table 4.7 Probable Yield from Hand Dug wells in Ado-Ekiti.

Periods	Type of well	Average water column	Average No of wells	Common well diameter (m)	Probable Yield (m^3/day)
Dry season	Shallow Deep	0.45m 3.5m	200 1500	1 1	22.5 1312.5
Rainy season	Shallow Deep	1.5m 6.0	200 1500	1 1	75 2250

Source: Field Survey.

From the above Table, the average daily yield is $915m^3$/day

Table 4.8 Yield from Some Boreholes at Ado-Ekiti

Location	Year of drilling	Depth (m)	Overburden Thickness (m)	Depth to Aquifer and Thickness (m)	Type of Submersible pump	Hole Size (mm)	Yield (L/S)
Mary Assumpter	1986	60	9	15(39)	1 Hp KSB	150	5.26
TOBH Water (Opopoghooro)	1987	54	9	9(45)	1.5 Hp KSB	125	15
University of Ado Ekiti	1989	63	12	12(23)	3 Hp Prauckline Model	150	18.75
Ajibola Poultry (Ilawe Rd.)	1992	60	9	15(15)	1.5 Hp SEEA	150	6.88
Federal Polytechnic	1993	75	6.5	9(64)	1.5 Hp Groundfos	150	12.5
Iworoko Rd (Opposite Aiyemi Garage.)	2000	60	18	24(30)	1 Hp KSB	150	7.23

Source: Benin Owena River Basin Authority

Table 4.8 is a result of the work done on underground water in Ado Ekiti. From this table the possible yield of the borehole mentioned ranges between 5.26l/s to 18.75l/s. These yields were all calculated from the pump test carried out by the driller. This can be said to negate the earlier report on the groundwater yield. This is also a proof that to an extent the ground water can be put into temporary use as an alternative source but just for a period of time.

From the field survey, the area where the charnockite underlay spread happens to be part of the central core area of the city which is thickly populated i.e. about 60% of the population residing there with 25 to 30 people in a building. In the newly developed areas where we have a population of about 40% residing, there are no water extension lines and so they depend mostly on wells and rainwater. Averagely 16 people live in a building here.

4.6.3 Surface water Assessment

Surface water is water stored or flowing on the earth's surface. The surface water system continually interacts with the atmospheric and subsurface water systems

Ado Ekiti is blessed with a reasonable number of such surface waters e.g. rivers, streams and springs. The town's relief and drainage pattern is such that most of the streams and springs have their sources within the town and drain in either eastward or southward direction. Surface water storage in drains and reservoirs has been the most feasible approach in water supply programmes.

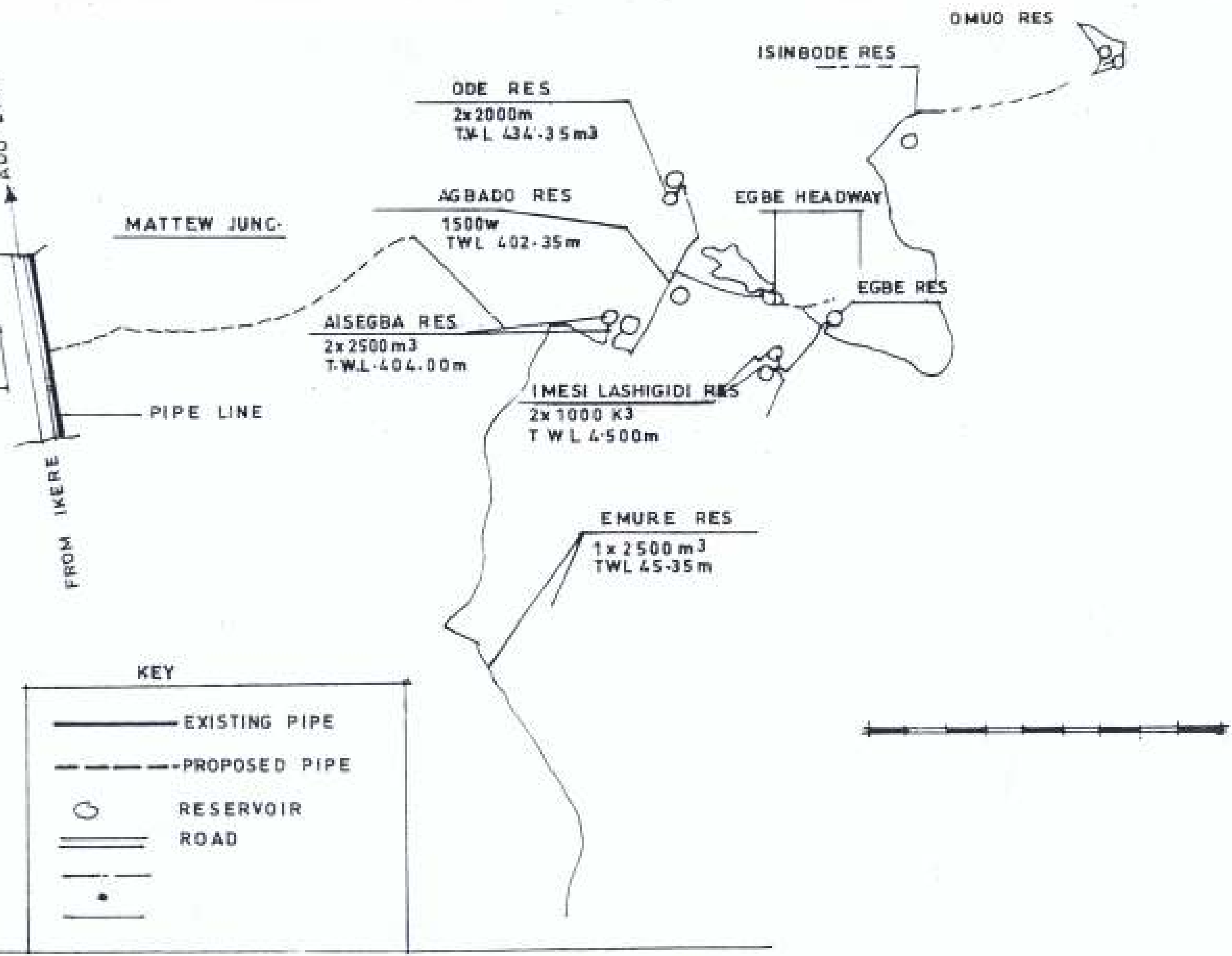
Ureje River Water Supply Scheme

The already harnessed rivers for the existing supply to this region is Ureje. The Ureje water scheme, the main source of existing potable water supply in Ado Ekiti has a designed capacity of $4930m^3$/day. This according to the State Water Agency is to be increased soonest to at least $9860m^3$/day.

The present total possible water supply to the region from the State Agency is only $4930m^3$ and the total water need is $33824m^3$. Therefore there is a deficit in the water supply to the tune of 85%. This enormous short fall necessitates augmentation from other existing schemes.

Other Complementary Schemes

Ero Water Supply scheme at Ikun-Ekiti with a designed capacity of $105000m^3$/day is complementing the supply to Ado Ekiti with $8000m^3$/day of treated water. If this supply is steady, the total deficiency will be $20894m^3$ when the quantity from groundwater is neglected so as to serve as alternate supply in case of any failure from the supply Agency.



SCHEAMATIC PIPELINE DRAWING FROM LITTLE

Little Osse water scheme at Egbe Ekiti with a designed capacity of 84000m^3/day is evaluated to determine the possible quantity of water that could be withdrawn from here. Presently, this little Osse scheme designed to feed 66 towns and villages is only serving 11 rural settlements/villages. This means that the scheme is being underutilized. Only about 17% of its installed capacity is being used. Therefore out of the balance of 80% expected production i.e. 67200m^3/day reasonable quantity can be used to argument the supply at Ado Ekiti.

Assuming also that the 11 towns being fed have normal growth rate then only about 20-30% of its production will be needed. If an allowance of 10% is made for other rural settlements not yet connected, then about 60% of its production capacity, that is 50400m^3 is available to supplement the supplies at Ado Ekiti (Fig. 4.1)

TABLE 4.9 **BALANCE OF WATER REQUIRED TO MEET DEMAND**

Year	Probable Total water need (m^3/day)	Probable supply from Water Agency (m^3/day)	Deficit	
			(m^3/day)	%
2003	33824	4930	28894	84
2010	44197	17860	26337	60
2015	55112	17860	37252	68
2020	68909	17860	51049	74
2025	93554	68260	25294	27
2030	116375	68260	48115	41
2040	179114	68260	110854	62

Table 4.10 Water need if all the considered schemes are assumed in use.

Year	Probable Total water need (m^3/day	Probable supply from Water Agency (m^3/day)	Supplies (m^3/day)	Deficit (m^3/day	Remark
2003	33824	68260	39366	-	If Ureje is doubled, Ero restored and little Osse looped
2010	44191	68260	24069	-	
2015	55112	68260	13148	-	Work on River Ogbese suppose to start and to be completed before year 2020
2020	68909	68260	-	649	
2025	93554	68260	-	25294	
2030	11637	68260	-	48115	
2040	179114	68260	-	110854	

On the basis of this projection a total of 63,330m^3 of potable water will be available for Ado-Ekiti. The present 2089m^3 deficit can be adequately taken care of. Assuming

Ado-Ekiti experiences a continuous industrial/commercial development and institutional growth in the years considered as highlighted in Table 4.5, the projected total water need would keep on increasing. If supply from these schemes are steady, then the water need of the town/city will be adequately met until about year 2015. By the year 2020 a deficit of $649m^3$ is envisaged. By the year 2025 the deficit would be $25294m^3$ and by year 2040 the deficit would have increased to $110854m^3$. Little Osse and other schemes will only be enough for the next 17 years (Table 4.10).

River Ogbese Schemes

Many of the rivers within Ado vicinity are tributaries of Ogbese. The rivers include Afiǹ, Elemi, Airi and their various tributaries. Water from these rivers is not used domestically but for washing.

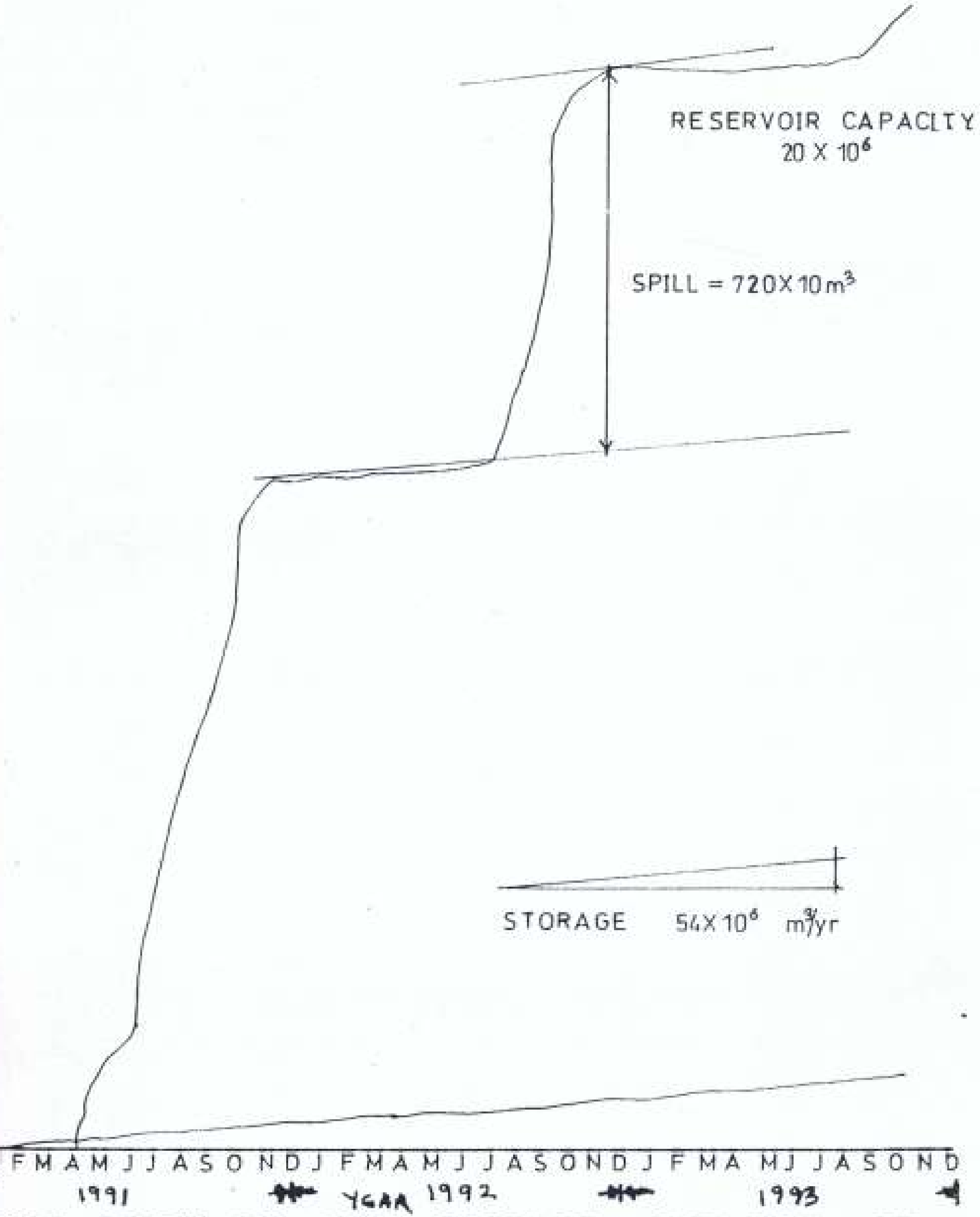
River Ogbese is perennial according to the hydrological data from Benin Owena River Basin Authority (1991 – 1993). These hydrological data are detailed in Appendix 1

This river is physiographically confined at Ago Aduloju and along Ikere/Ise Road.

With more tributaries flowing to this river around this place a possible increase of the catchment area may be made to have more impoundment. With necessary geophysical investigation carried out plus detailed design of the dam the river might be able to possibly provide enough supply even if there is short fall from any of the complementing schemes.

Table 4.11 The storage capacity of River Ogbese at Aduloju using the mass curve

MONTH	INFLOW X $10^6 m^3$	Cumulative Inflow x $10^6 m^3$	Uniform Demand x $10^6 m^3$
Jan. 1991	0.4	0.4	4.5
Feb.	3.0	3.4	9.0
Mar.	8.0	11.4	13.5
April	5.3	16.7	18
May	148.4	165.1	22.5
June	53.5	218.6	27
July	335.9	555	31.5
August	179.7	734.2	36
September	145	879	40.5
October	311	1190	45
November	60.8	1251	49.5
December	3.8	1255	54
Jan. 1992	1.3	12.56	58.5
Feb.	0.3	12.56	63
Mar.	1.7	1258	67.5
April	3.6	1262	72
May	8.8	1271	76.5
June	15.6	1286	81
July	4.2	1290	85.5
August	169.1	1459	90
September	181.3	1641	94.5
October	324.7	1965	99
November	45.5	2011	103.5
December	2.4	2013	108
Jan. 1993	1.8	2015	112.5
Feb.	1.3	2016	117
Mar.	1.2	2018	121.5
April	2.4	2020	126
May	2.4	2022	130.5
June	4.4	2027	135
July	6.6	2033	139.5
August	5.5	2039	144
September	49.1	2088	148.5
October	44.8	2133	153
November	Nr	Nr	Nr
December	Nr	Nr	Nr



G 4.2 GRAPH OF THE STORAGE CAPACITY OF
RIVER OGBESE AT ADULOJU ADO-EKITI

4.7 Analysis and Results

4.7.1 Population Projection and Water Demand

It is determined that with the projected population there is drastic increase in the water demand, especially from year 2020 upwards. From the earlier calculation the population distribution against the water demand is as per Table 4.12:

Table 4.12 Population Projection and Water Demand.

Year	Population	Water demand (m^3/day)
2003	201,816	33,824
2010	274,644	44,191
2015	350,523	55,112
2020	447,366	68,909
2025	570,965	935,543
2030	728,712	916,375
2040	1,186,995	179,114

From the existing water scheme i.e. Ureje, Ero and little Osse a total of 63330m^3 of potable water can be possibly made available for Ado-Ekiti. This quantity will be achieved by the time the State Water Agency doubles Ureje's production, restores back the supply from Ero dam to Ado and loops Little Osse with the existing line at Ado.

4.7.2 Water Supply to Meet Projected Demand

From the earlier calculations, if the proposed supply of 50400m^3 is added to the Ureje Production of 4930m^3 and that of Ero with 8000m^3, then a total of 63,330m^3 which will only be adequate up to year 2015 can be made available. By the year 2020 as per Table 4.10 the supply would have gradually become inadequate.

But if River Ogbese as is established to be a feasible source is harnessed on or before year 2020 then the deficit envisaged would have been adequately taken care of. River Ogbese may be harnessed at Aduloju if there is no enough record available on this river along Ise Road. $126.25 \times 10^6 m^3$ is quite satisfactory and will serve this city in many years to come.

At Ago Aduloju on latitude 7° 36' N and longitude 5° 2' E, the river has the following as its annual runoff volume in $10^6 m^3$.

For	1991 -	279
	1992 -	753.3
	1993 -	159

The. table of discharge from this river along this route, the discharge hydrographs, area capacity curve and rating curves are detailed in the appendix.

From the water level hydrographs of the 3 years considered (1991-1993) the increase in water level starts from April and became very high from August to October of every year. Also from the water discharge hydrographs averagely there was much discharge from August to October every year. All these indicate that river Ogbese apart from being a perennial river has enough discharge that can possibly be harnessed in the future and treat for public use and consumption.

From the hydrological data a dam with the following appurtenances, an elevation of 388.62m area of $7075 \times 10^2 m^2$, height of 7.62 will have a reservoir capacity of about $50.54 \times 10^6 m^3$. If the elevation is 396.24m and area $1287 \times 10^3 m^2$ with the same dam height then the reservoir capacity of $126.25 \times 10^6 m^3$ can be achieved.

Also from the available hydrological data both the cumulative inflow and the rivers storage capacity here are calculated and graphs plotted using the mass curve Fig.4.2 and Table 4.11.

The river along Ikere/Ise Road on Latitude 7° 28' N and Latitude 5° 20' E has an inadequate hydrological data that cannot be analysed. However the data obtained by AIS consultant (Aug 1993) was relied upon.

The catchment area is estimated to be $1312.5 km^2$. If a dam with a height of 13m is constructed, then the possible impoundment of about $15 \times 10^6 m^3$ can be made.

Considering the above statement the following conclusions are arrived at

(i) It is established that Urban centre like Ado Ekiti is not having adequate water supply.

(ii) If the available water resources potentials are optimally utilized then the projected future water demand of this region can be met.

(iii) It is established that little Osse headworks at Egbe Ekiti can serve Ado for the next 12 years but requires (a) construction of a booster station between Ijan and Ado because of the topography of this area as revealed from the earlier survey work done on the connection with Little Osse headworks (survey drawing at Appendix iii) (b) total rehabilitation of this headworks including reconditioning of the high lift pumps meant then for Akoko areas.

(iv) There can still be conjunctive use of the surface and ground water to an extent i.e. in places where there are quartzite spread and fractured weathered rock.

CHAPTER FIVE

WATER QUALITY ANALYSIS FOR THE CONSIDERED RIVERS.

5.1 General

Water quality supply of urban territories remain a big problem. In the centralized water distribution systems, breakdowns, pressure drops and interruption of water supply are common, increasing the risk of secondary contamination of water thus posing a health risk.

Urbanization is an inevitable and unavoidable feature in the process of development. In some areas rapid urbanization has taken place because of rural-urban migration, expansion of urban territory and growth of population in urban areas.

In these circumstance, the capacity of urban centre to cater for the basic needs of growth is heavily challenged. Implication of such urbanization are poverty, gross inequality, high unemployment, underemployment, over crowded housing, proliferation of slums and squatters, deterioration of environmental conditions, highly inadequate supply of clean water, high incidence of diseases, over crowding in schools and hospitals, overloading in public transports and increase in traffic jams, road accidents, violent crimes and social tension. These features are characteristics of urban centres in which Ado Ekiti is not left out.

Ado Ekiti's population has increased drastically with more industries springing up so that demand for water is on the increase. The acceleration of urbanization posses new challenges for parties aiming to serve the poor and address poverty. Rural to urban migration is inevitable because of the scope of employment, income and other facilities in such centres.

5.2 Quality Aspects

The operators of water supply systems are responsible for regularly monitoring the quality of the water supplied to the consumers and its conformity with the WHO guideline most especially the bacterial requirement that no detectable bacteria in each

100ml of water. Many substances may be left to exist in a public water supply only to a limited extent. Certain properties of the water must also be controlled within specified limit to provide a wholesome and palatable supply. Conventional treatment methods such as chemical coagulation or lime softening are effective for removing many of the heavy metals and radioactive materials such as radium.

No single treatment process is effective for complete removal of all inorganic contaminants, but fortunately, many, can be removed from water by coagulation or lime softening.

Tables 5.1, 5.2 and 5.3 show the concentration of various elements in raw and treated water from both complementary schemes earlier mentioned and that of Ureje, the major source of supply to the study area.

Table 5.1 Parameters in Both Raw and Treated Water from Ureje Scheme.

Parameter	Raw	Treated
Odour	Unobjectionable	Unobjectionable
Colour (Hu)	20	5
Temp ^{0}c	26	26
pH	7.4	7.0
Turbidity (NTU)	22	7
Conductivity ms cm^{-1}	0.03	0.03
Total Dissolved Solids mg/l	142.86	128.57
Acidity mg/l	0.6	0.4
Total hardness mg/l	2.6	2.5
Calcium hardness mg/l	10	11
Magnesium hardness mg/l	16	14
Chloride mg/l	22	23
Iron mg/l	0.3	0.1
Bacterial count/100ml sample	TNC	TNC
Coliform count MPN	Nil	Nil

Source: Ekiti State Water Corporation.

TNC means Too Numerous to Count.

Table 5.2 Parameters in Both Raw and Treated Water from Ero.

Parameter	Raw	Treated
Odour	Unobjectionable	Unobjectionable
Colour (Hu)	10	5
Temp ^{0}c	26	26
pH	7.4	6.4
Turbidity (NTU)	12	4
Conductivity ms cm^{-1}	0.02	0.03
Total Solids mg/l	57.14	60
Dissolved solid mg/l	57.14	60
Acidity mg/l	0.5	0.5
Total hardness mg/l	18	18
Calcium hardness mg/l	4	10
Magnesium hardness mg/l	14	8
Chloride mg/l	17	20
Iron mg/l	0.1	0.1
Bacterial count/100ml sample	TNC	TNC
Coliform count MPN	160	Nil

Source: Ekiti State Water Corporation.

Table 5.3 Parameters in Both Raw and Treated Water from Little Osse.

Parameter	Raw	Treated
Odour	Unobjectionable	Unobjectionable
Colour (Hu)	20	5
Temp ^{0}c	26	26
pH	7.2	8.8
Turbidity (NTU)	8.0	5.0
Conductivity ms cm^{-1}	-	-
Total Solids mg/l	70	85.71
Dissolved solid mg/l	70	85.71
Acidity mg/l	0.4	0.3
Total hardness mg/l	29	13
Calcium hardness mg/l	11	5
Magnesium hardness mg/l	18	8
Chloride mg/l	15	25
Iron mg/l	0.2	0.1
Bacterial count/100ml sample	TNC	0.1
Coliform count MPN	160	Nil

Source: Ekiti State Water Corporation.

Table 5.4 compares the concentration of each contaminant with the WHO standards and International Permissible Limits (copies at Appendix)

Table 5.4 Comparison Of The Treated Water Parameters with WHO Guidelines And International Limits.

PARAMETERS	TREATED WATER FROM			WHO Guidelines	International Limits
	UREJE	ERO	Little Osse		
Colour (Hu)	5	5	5	15 TCU	6.5-9.2
Temp ^{0}c	26	26	26	NA	NA
pH	7.0	6.4	8.8	6.5 to 8.5	NA
Turbidity (NTU)	7	4	5.0	5NTU	25NTU
Conductivity mš cm^{-1}	0.03	0.03	NA	NA	NA
Total solids mg/l	-	6.0	85.71	NA	NA
Total Dissolved solids mg/l	128.57	60	85.71	1000mg/l	NA
Acidity mg/l	0.4	0.5	0.3	NA	NA
Total hardness mg/l	25	18	13	NA	NA
Calcium Hardness mg/l	11	10	5	500 mg/l	200 mg/l
Magnesium Hardness mg/l	14	8	8	NA	150
Chloride mg/l	23	20	25	NA	600
Iron mg l	0.1	0.1	0.1	0.3 mg/l	1.0
Bacterial count ,100 ml sample	TNC	TNC	0.1	NA	NA
Coliform count (MPN)	Nil	Nil	Nil	Absent in 100ml	NA

In case of colour of the finished product from the 3 schemes, the treatment profer has been able to reduce this to the permissible level. And for the pH of the treated water from both Little Osse and Ureje it is within the allowable limit while that of Ero needs to be controlled. This will increase the pH to the permissible level thereby providing a less corrosive finished water. In this case, liquid caustic soda is commonly used because of its ease of handling. But when a large increase in pH is required, lime is usually the most economical choice. Lime, however may add turbidity. If lime is used for post filtration pH adjustment, it is generally best to use a lime saturator to ensure that no turbidity is added. Turbidity, from treated water analysis is less than the maximum permissible, so it is still acceptable. For the total dissolved solids, on treating, it thus reduces to the allowable limit.

From the analysis, the rest of the parameters fall within the allowable limit except the bacterial count in 100ml sample which is too numerous to count. Except for Little Osse the 2 other schemes; Ureje and Ero require better effective disinfections with chlorine gas or ozone. This will reduce the bacterial count.

Table 5.5 shows the concentration of various elements in the water from Ogbese river during dry and wet season.

Table 5.5 Concentration of inorganic elements in River Ogbese

ELEMENT	CONCETRATION IN RAW WATER	
CONTAMINANT	DRY SEASON	WET SEASON
CALCIUM	36mg/L	28mg/L
MANGANESE	0.005mg/L	0.008mg/L
MAGNESIUM	20mg/L	10mg/L
IRON	0.64mg/L	1.21mg/L
TURBIDITY	23 FTU	113 FTU
PH	6.0	5.6
COLOUR	20	30
TOTAL DISSOLVED SOLID	100mg/L	100mg/L
ACIDITY	-	-
TOTAL HARDNESS	56mg/L	38mg/L
CHLORIDE	17mg/L	8mg/L

Source: From Field Survey

River Ogbese is analysed to confirm whether the water can be treated to WHO standards. Iron is frequently found in raw waters and a minute trace can usually be found in all waters delivered to the consumer when the water has been in contact with iron pipes. This metal is not harmful but there are objections to the presence above a certain amount.

(i) It can make water unpalatable imparting a bitter taste to the water when present in large amounts.

(ii) When the water is exposed to air and takes up oxygen the iron is likely to precipitate and the deposits cause brown stains upon sinless, baths, wash basins and laundry.

The WHO international standard for drinking water gives 0.1mg/L as the highest desirable level and 1.0mg/L as the maximum permissible. The range of 0.64mg/L to 1.2mg/L from the analysis indicates that the concentration is high though it is still within the maximum permissible according to WHO's International standard during the dry season. The treatment of this water with chlorine and lime will oxidize the iron which will eventually precipitate according to the chemical reaction equation below.

$$2\ FeS0_4.7H_20 + 2\ Ca(0H)_2 + \frac{1}{2}\ 0_2 \longleftrightarrow 2Fe\ (0H)_3 + 2CaS0_4 + 13H_20$$

Calcium is present in water as bicarbonate causing predominantly temporary hardness while its chloride, sulphate and nitrate cause permanent hardness. From the result of the analysis there is limited calcium present hence it is acceptable with the WHO standard.

Manganese is a troublesome element in water even when present in small quantities. It forms a deposit in water in the presence of oxygen or when chlorine is added. It can then coat the within of pipes with a black slime. This slime is eventually detached from the walls of the pipes and conveyed through service pipes to the consumers to whom it is most objectionable. Manganese is often associated with iron in water and has a behaviour which is similar except that the deposits are cumulative. High quantities of manganese are toxic.

From the result of the analysis the manganese concentration ranges between

0.005mg/l in dry season to 0.008mg/l in wet season. These values are far below the highest desirable level given by WHO standard for drinking water.

Even with the chlorine that is going to be used as disinfectant in the treatment, iron and manganese will be chemically oxidized by free chlorine residual.

$$Fe^{++} + Mn^{++} + \text{oxygen free chlorine} \xrightarrow[\text{Residual}]{} Fe\,0_2\downarrow + Mn0_2\downarrow$$

insoluble metal oxides

Turbidity can be said to be the content level of particulate matters in any source water. The WHO standards stipulate 5 NTU as the approved level of turbidity permitted in any drinking water. From the analysis of Ogbese River, the turbidity range, between 23 NTU and 133 NTU which is very high compared to the allowable level hence conventional rapid sand filtration may be used for this high turbidity situation. For the pH contaminant, according to WHO the maximum permissible level ranges between 6.5 to 8.5. From the analysis the pH shows that the water is acidic but can easily be treated to fall within the permissible level with the lime and caustic soda to be added.

Colour: is caused by naturally occurring organic matter that is the result of the natural decay of vegetable matter, primarily leaves, grasses, roots and wood. The resulting soluble or colloidal dispersion of semi-soluble matter are a mixture of primarily aromatic hydrocarbon polymers with carboxylic groups.

Carbonate Hardness: in the form of calcium is to be removed by adding lime to softening. Lime plus soda added removes both carbonate and noncarbonate hardness. The lime or lime – soda ash process removes only calcium carbonate hardness down to a minimum of about 35mg/l

With the result of the analysis of raw water from Ogbese, conventional treatment method with rapid sand filtration may be considered. Lime, caustic soda and chlorine are very necessary for the treatment purposes.

CHAPTER SIX

CONCLUSION AND RECOMMENDATION

CONCLUSION

s discovered that the influx of people to this city after the creation of Ekiti State and bsequent industrial/commercial growth are the main reasons for inadequate water pply.

om this study, there is suggestion that little Osse water supply scheme be looped with existing mains at Ado-Ekiti close to Matthew junction. With the looping of this line, toring the boost from Ero and upgrading the production from Ureje in earnest, the nediate and the projected water needs for the next 12 to 14 years can be adequately t.

ver Ogbese is also considered to be feasible as additional source of supply to the sting supply so the need to harness it for future need. For this reason there is a ggestion that necessary hydrogeophysical/geophysical investigation and detailed sign be embarked upon at least 5 years earlier than the proposed time of plementation and completion of the project.

s envisaged that if River Ogbesse is harnessed at Aduloju it will have enough poundment that can sufficiently serve Ado Ekiti. However, it will be necessary to bark on necessary investigations to ascertain the possibility of harnessing it at re/Ise Road.

ere are more tributaries flowing into the river around here so there is possibility of ng able to have increased reservoir capacity. This impoundment might be able to e other towns like Ikere and Ise Ekiti as well. Though the piping from Aduloju to is less and cost might be reduced but more towns can be serviced through Ogbese kere Ise Road. The cost involvement and benefits of both impoundments can be npared for final selection of location considering the economical aspect.

s also discovered that newly developed areas in Ado-Ekiti have no water extension es. It is uncovered that despite the massive spread of unproductive geological mations, people still engage in indiscriminate digging of wells and drilling of boreholes.

It is also proposed that the underground water is just to serve as alternative supply for temporary use within a short period. Meeting long projected water demand of this city will in no small measure assist the development of the city. In fact the future will be bright for industrial and social developments and indirectly technological advancement.

6.2 RECOMMENDATIONS

The rapid urbanization process in Nigeria is generating huge challenges and both government and civil society agents have to develop strategies to cope with these challenges.

Hence, it is recommended that pipelines be extended to all areas where there are none in Ado-Ekiti. Replacement of existing damaged ones is also necessary as all these will improve the entire water supply and enhance the revenue base of the water agency. The State water agency can become self-sustaining financially in future if wastage is drastically reduced and there is optimal use of the available supplies.

There is need for total rehabilitation of this Little Osse scheme and reconditioning of the high lift pumps. Also because of the topographic terrain along Ado- Ijan road it is necessary to have a booster station at Ijan Ekiti to get water to Ado Ekiti.

Even though Ado Ekiti area has been classified as being poor in ground water potential, hand dug wells and borehole can still be constructed in conducive areas after thorough geophysical investigation of the sites under consideration. This will serve as additional or alternate source in case there is interruption of supply due to some technical problems.

Also for the borehole construction, the relevant body ought to visit the site and approve or disapprove the drilling of borehole, considering the numbers already in the area and how they can affect the existing water table to avert future havocs that this indiscriminate drilling of boreholes or deep well can cause the community and much financial involvement that can cause the government.

It is suggested that rainwater can be harvested and treated for just family domestic uses. Since it is generally believed that "Water is life," then any government that values development will not hesitate to expend more on the supply of potable water to the people. Water is the most essential social need and therefore it is necessary to provide it adequately in order to promote good health and continuous industrial development.

REFERENCES

Adebayo W.O (1987): Spatial Analysis of Stream Floods and Hazards in an Urbanized Environment: 'A Case Study of Ado-Ekiti' An Unpublished B.Sc. Dissertation. Geography Department. Ondo State University, Ado-Ekiti.

Adeduro A.D and Fadipe (1992): The effect of cyclic fatigue on the geo technical properties of same lateitic soils. A paper presented at 28th Annual NMGS Conference, Port Harcourt

Adeniyi A.O. (1993): "Soil and Vegetal Resources" Alpha Prints. A Division of Zed Biz Ltd.

Agunwamba, C.J. (2000) "Water Engineering Systems" Immaculate Publications Limited Enugu: Nigeria

Australian Academy and Technology Services and Engineering (1988); Urban Water Supplies. Australian Science and Technology Heritage Centre.

Bond H (1966): "The Protection For Humorous Demand J. AWWA 58 (2) Pp 1291 – 1294

Chilton J (2002): Dry or Drowning? Our Planet 9.4-Fresh Water. British Geological Society, London U.K.

CLIMAS (2003): Urban Water Study, University of Arizona.

Department of Operation Evaluation (2002) " Managing Urban Water Supply and Sanitation" World Bank Journal.

Ebisemiju F.S. (1993): "Ado-Ekiti Region" Alpha Prints, A Division of Zed & Biz Ltd.

Fadipe, A.A and Ibukun B.M. (1992) "Preliminary Studies on some Physio-chemical characteristics of Groundwater and Their Relationships with Bedrock Chemistry in Ado-Ekiti and Environs. A paper presented at the 28th Annual NMGS Conference, Port Harcourt.

Fadipe, A.A and Adeduro. (1993): Geology and the Mineral and Groundwater Resources. Alpha Prints, A Division of Zed & Biz Ltd

Fiji Government Online (2002): Ministry of Health. Plan Fluoridation in Water Systems. Ministry of Information

Haryadi T. & Schrudit G. (2001): "Groundwater Modelling for the Jakarta Area – HAG

Working Paper's No 116/116a. Unpublished. Reports. BGR Hannover and DEG Baduna.

Ibukun B M (1987) " The Relationship Between The Chemistry of Groundwater and Bedrock in Ado Ekiti and Environs" Unpublished B.Sc Project Report. Ondo State University. Ado-Ekiti.

I.R.C International Water and Sanitation Centre (2002) "Mitigating the Impact of Urbanization on Freshwater Resource"

IRC Hon (2002): Between rural and urban International Water and Sanitation Center.

Linsley K R and Franzini J (1964) "Water Resources Engineering" McGraw-Hill Book Company USA pg 154-156.

Lipchin C (1999): Perception of Water use in the Arava Valley of Israel and Jordan.

Lowgren M. Vain A et Hjerpe M (2001-2003): Economics of Sustainable Urban Water Management: Department of Water and Environmental Studies. Linköping. University

Managing Water For African Cities (MAWAC) Programme (2002): African Resources Centers and Urban Water Management. International Water and Sanitation Centre

Managing Water For African Cities (MAWAC) et Peter (2002): Mitigating The Impact of Urbanization on Freshwater Resources. International Water and Sanitation Centre

Milburn A (1996) " A Global Freshwater Convention – the Best Means Towards Sustainable Fresh water – Management prol. Introduction Water Symposium 4 – 9 August Pp 9- 11.

Ministry of Works. Water Department. Malawi (1988-2003) Piped Supplies For Small Communities in Malawi.

Nienczynowicz J (2002) "Immolation Trends in Urban Water Supply and Savanna. Department of Water Resources Engineering University of Lund, Sweden.

Olanrewaju V.O (1981) "Geochemistry of the chanockitic and grantic rocks of the basement complex around Ado – Ekiti and Akure S.W Nigeria unpublished Ph. D Thesis University of London

Postel S (1999): "Every Precious Drop Stretching Water Supplies," Worldmatch Institute, US.

Rahaman M (1991): Review of the Basement Geology of S.W Nigeria.

Reid C (2001): Urban water Journal. Elsevier Publishers U.K.

Russ S 1995-2000: Seattle Daily Journal. Seattle.

The World Bank Group (2002) LGU Urban Water and Sanitation (LGUUDVSP) Project 182 Department of Interior and Local Government (OLLG). Office of Project Development Services. 50 Floor Francisco Gold Condominium ESA Corner Moagniahel St. Dilimen, Owezon City, Philippines.

Webb Jason (1998) "Clean Technology Approach To Urban Water Resource Management" Eng D in Environmental Technology Scheme by University of Surrey and Brunel University, United Kingdom.

APPENDIX

APPENDIX I

GUIDELINES FOR DRINKING WATER QUALITY (WHO 1982)

CHARACTERISTIC	ACTION LEVEL
Arsenic	0.05 mg/l
Cadmium	0.005 mg/l
Chromium	0.05 mg/l
Cyanide	0.01 mg/l
Fluoride	1.5 mg/l
Lead	0.05 mg/l
Mercury	0.001 mg/l
Nickel	0.1 mg/l
Nitrate and Nitrite Nitrogen	10 mg/l
Nitrate Nitrogen	1.0 mg/l
Seleneum	0.01 mg/l
Chlorine	250 mg/l
Sulphate	400 mg/l
Hardness as $CaC0_3$.	500mg/l
Total dissolved solids	1000mg/l
Aluminum	0.2mg/l
Copper	1.0mg/l
Iron	0.3mg/l
Manganese	0.1mg/c
Sodium	200mg/c
Zinc	5Ng/l
Chlorophenols	0.1Ng/l
Chloroform	30Ng/l
DDT	1.0Ng/l
Hepatachlor	30Ng/l
Lindane	3.0Ng/l
Monochlorobenzene	0.1Ng/l
1.4 dichlorobenzene	0.1Ng/l
2.4.D	100Ng/l
Gross alpha activity	0.1Bq/l
Gross beta activity	1.0Bq/l
Colour beta activity	15 TCU
Turbidity	5 NTU
Taste	not objectionable to 90% of consumers
PH	6.5 to 8.5
Cliforms	absent in 100ml

(Source: Tebbutt, 1983)

APPENDIX II

International Limit for Substances affecting the acceptability of water for domestic purposes [Concentration (mg/l)]

	International Limits	
Substance	Highest Desirable	Maximum Permissible
Phenotic Compound (as phenol)	0.001	0.001
Fluoride (as F)		0.2-1.7
Nitrate (as NO_3)	-	-
pH	7.0-8.5	6.5-9.2
Copper (as Cu^{2+})	0.5	1.5
Iron (as Fe^{2+})	0.1	1.0
Manganese (as Mn^{2+})	0.05	0.5
Zinc (as Zn^{2+})	5.0	15
Magnesium (as Mg^{2+})	50-150	150
Sulphate (as SO^{2-}_4)	200	400
Hydrogen sulphate (as H_2S)	-	-
Chloride (as Cl)	200	600
Chlorine (free)		
Anionic Detergent	0.2	1.0
Ammonia (as NH_3)	-	-
Carbon dioxide (free)		
Calcium (as Ca^{2+})	nil	200
Mineral	75	0.5
Mineral oil with high sulphur content	0.01	0.1
Turbidity (units)	5	25
Organics	-	-

Source: FEPA (1991)

APPENDIX III

– OGBESE RIVER.

a) ANNUAL REPORT OF GAUGE HEIGHT AND DISCHARGE (1991).

ATER – STAGES

N CENTIMETERS)

STATION: ADO ADULOJU
RIVER: OGBESE

ATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
	30	47	88	47	97	32	148	291		218	273	83
	28	44	78	41	80	227	143	253	212	226	261	82
	26	43	71	37	65	214	300	235	269		241	80
	24	42	62	34	82	195	300	228	251		222	79
	22	30	58	28	118	182	300	215	239		215	77
	20	29	51	27	218	176	288	217	258		187	75
	18	28	169	98	142	183	280	239	266		182	73
	16	28	113	84		191	277	224	259		175	76
	13	26	82	70		185	260	212	233		170	69
	12	26	75	63	130	210	256	209	214		161	68
	10	25	75	55	129	200		203	232		155	68
	10	24	64	51	124	159	274	183	215		150	67
	10	23	62	48	161	146	268	185	210		147	65
	10	89	58	56	198	134	248		209		136	64
	76	85	164	98	206	134	300	222	204	298	130	63
	61	77	124	90	225	137	300	181	200	295	123	60
	45	73	99	84	300	142	300	168	199	291	121	54
	35	66	99	76	300	135	300	233	191	287	119	51
	26	64	85	64	300	132	300	252	203	283	114	44
	18	63	55	112	300	124	300	270	206		111	41
	16	61	41	114	300	118	300	242	198		109	66
	13	56	38	84	300	112	300	231	195		107	68
	13	53	35	75	294	107	300	228	193		104	68
	12	61	27	70	248	85	300	224	187		101	57
	10	77	25	52	223	85	290	234	185		98	59
	18	74	19	56	210	59	300	272	189		96	62
	20	74	16		197	90	300	169	213		93	60
	8	97	25	71	170	83	300	246	221		59	58
	7		25	68	182	175	300	241	219		85	58
	7		21	74	147	163	300	226	217	294	89	57
	8		19		134		300		215	286		56
AX	76	97	164	114	300	227	300	291	269	298	273	83
N	6	21	16	23	55	29	142	161	190	216	84	41

AXIMUM	300	cm	17/05/91	03/05/91
	300		31/05/91	

OURCE: BENIN-OWENA RIVER BASIN AUTHORITY, BENIN

ANNUAL REPORT OF GAUGE HEIGHT AND DISCHARGE (1992).

WATER – STAGES

(IN CENTIMETERS)

STATION: ADO ADULOJU

RIVER: OGBESE

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1	55	35		36	42	97	42	215	300	284	182	69
2	55	35		12	18	95	16	215	259	287	200	68
3	53	34		33	30	95	34	215	238	267	200	67
4	53	34		80	70	100	90	214	231	290	200	67
5	50	33		70	70	100	75	270	222	290	192	65
6	49	32		99	100	107	95	260	210	290	190	65
7	48	31		77	96	102	80	247	252	289	185	65
8	48	30		81	90	102	75	247	230	274	176	60
9	46	36		93	93	108	80	240	228	274	170	55
10	46	35		60	74	113		238	220	266	169	52
11	46	34		69	70	118	70	209	211	290	167	50
12	46	32		70	70	118	60	207	219	277	151	62
13	46	31		74	69	122	65	204	279	274	148	60
14	46	29		70	69	123	70	219	221	274	143	58
15	46	29		58	58	119	80	219	231	300	140	58
16	46	28		75	75	102	85	192	192	300	130	56
17	46	27		80	80	97	91	192	192	300	127	53
18	46	26		77	77	97	20	200	220	296	125	53
19	46	25		72	100	99	10	200	246	288	121	53
20	45	25		62	94	98	35	195	288	277	118	47
21	45	24		52	94	90	59	195	275	280	110	45
22	45	24		40	96	98	54	156	245	290	107	42
23	45	23		20	96	97	35	156	224	290	100	58
24	45	23		32	97	100	49	196	211	290	100	58
25	43	20		40	100	96	50	192	260	290	98	58
26	40	20		29	100	96	66	185	260	296	95	54
27	39	20		40	111	101	44	291	243	286	90	50
28	39	18		40	101	118	40	300	237	274	90	50
29	38	18		51	99	118	33	289	237	271	81	48
30	36				97	117	85	287	220	260	71	48
31	35				97		35	187		196		48
MAX	55	35			99	111	118	95	300	300	300	69
MIN	35	18			12	18	95	10	156	179	196	42

MAXIMUM 300 cm 29/08/92 17/10/92

DATE DATE

MINIMUM 10 cm 19/07/92

1– OGBESE RIVER.

(a) ANNUAL REPORT OF GAUGE HEIGHT AND DISCHARGE (1993).

WATER – STAGES

(IN CENTIMETERS)

STATION: ADO ADULOJU
RIVER: OGBESE

DATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
1	64	38	37	39	60	47	47	90	180	172		
2	63	38	37	39	61	47	60	100	185	155		
3	62	40	40	39	63	47	75	100	170	149		
4	61	40	41	45	64	65	95	100	174	148		
5	60	40	41	60	55	80	80	150	173	140		
6	59	39	43	60	53	75	85	125	171	140		
7	59	38	43	53	50	60	86	130	176	135		
8	58	37	44	50	50	65	87	140	167	128		
9	58	36	46	54	55	70	89	160	160	146		
10	57	36	46	54	60	68	90	180	155	160		
11	57	35	48	54	59	69	92	200	158	165		
12	56	35	46	57	59	69	94	100	159	143		
13	56	35	40	59	50	70	97	120	143	140		
14	54	40	49	40	50	70	80	125	145	140		
15	53	60	49	40	50	72	83	140	147	138		
16	52	49	50	40	68	73	85	160	149	150		
17	50	20	50	40	62	75	88	180	134	125		
18	49	30	50	45	62	77	70	180	136	180		
19	47	60	51	47	62	78	72	200	138	175		
20	45	57	51	55	63	60	73	100	200	193		
21	45	60	59	60	64	69	75	120	125	110		
22	44	52	59	65	65	70	76	125	127	180		
23	41	52	42	68	60	80	77	130	110	170		
24	40	53	40	50	49	78	78	145	108	165		
25	40	54	40	55	48	75	79	165	106	150		
26	40	57	39	57	48	74	60	175	104	150		
27	40	59	39	60	49	73	60	190	130	148		
28	39	55	39	75	50	72	59	200	180	140		
29	39		39	91	50	71	59	200	185	130		
30	38		39	80	49	71	59	200	195	130		
31	38		39		48		59	200		125		
MAX	64	60	59	80	65	80	95	200	195	193		
MIN	38	20	37	39	47	47	59	90	104	125		

MAXIMUM	200	cm	19/08/93	31/08/93
			DATE	DATE
MINIMUM	20	cm	17/02/93	

ATER DISCHARGE
(IN M^3/S

1991

STATION: ADO ADULOJU
RIVER: OGBESE

AN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC
13	0.51	3.48	0.051	4.80	0.15	0.15	135.00	57.74	53.25	108.00	2.96
10	0.41	2.37	0.32	2.65	62.45	62.45	88.50	104.60	61.54	96.00	2.83
06	0.38	1.70	0.24	1.30	51.60	51.60	70.00	85.50		79.25	2.85
06	0.35	1.18	0.18	2.93	39.00	39.00	63.33	73.75		58.48	2.40
04	0.13	0.94	0.10	8.50	31.80	31.90	52.50	93.20		52.50	2.32
02	0.12	0.64	0.07	53.20	29.00	29.00	54.30	103.40		34.20	2.10
01	0.10	24.50	4.88	15.10	32.20	32.20	73.75	94.10		31.80	1.90
01	0.10	7.35	3.00		37.00	37.00	59.96	68.00		28.00	2.20
00	0.06	2.93	1.65		33.00	33.00	49.80	51.60		24.50	1.60
00	0.06	2.10	1.22	11.40	48.00	48.00	47.50	67.00		21.50	1.52
00	0.06	2.10	0.80	11.12	48.00	43.00	44.20	52.20		19.00	1.52
00	0.06	1.25	0.64	9.56	20.50	20.50	32.20	48.00		17.00	4.45
00	0.06	1.18	0.53	21.50	15.80	15.80	33.00	47.50		15.90	1.30
00	3.00	0.94	0.86	40.00	12.30	12.30		47.50		12.80	1.25
20	3.12	0.94	4.88	45.75	13.30	13.30	111.00	44.60		11.40	1.22
11	2.32	23.00	3.72	60.70	15.10	15.10	104.00	43.00	142.50	10.28	1.05
44	1.90	9.66	3.00	145.00	15.10	15.10	80.00	41.00	129.00	9.33	0.75
20	1.35	4.95	2.20	145.00	12.60	12.60	145.00	37.00	135.00	8.90	0.64
06	1.25	2.93	1.25	145.00	11.80	11.80	145.00	44.20	125.60	8.65	0.51
02	1.22	0.80	7.17	145.00	9.66	9.66	145.00	45.75	123.00	7.50	0.41
01	1.11	0.32	7.50	145.00	8.50	8.50	145.00	40.00		7.00	0.32
00	0.86	0.26	3.00	145.00	7.17	7.17	145.00	39.00		6.35	1.36
00	0.70	0.20	2.10	138.70	6.00	6.00	145.00	38.70		8.00	1.52
00	1.11	0.07	1.53	80.00	3.12	3.12	145.00	34.00		5.68	1.52
00	2.32	0.06	1.18	58.22	3.12	3.12	133..00	33.00		4.75	0.90
00	2.00	0.02	0.86	48.00	1.00	1.00	145.00	60.70		4.60	1.25
00	4.80	0.01		39.60	3.72	3.72	145.00	57.74		4.10	1.05
00		0.06	1.70	25.50	2.96	2.96	145.00	47.60		3.80	0.94
00		0.05		31.30	28.00	28.00	145.00	54.30		3.12	0.20
00		0.03		15.90	22.50	22.50	145.00	52.50	138.70		0.88
00		0.02		12.30			145.00		128.30		
20	4.80	24.50	7.50	145.00	62.45	145.00	135.00	104.60		109.00	2.96
15	1.15	3.10			20.65			55.92		23.46	1.43
00	0.05	0.01	0.07	1.30	0.15	15.50	31.10	33.00		3.12	0.41
47	32.05	96.05	58.73	1605.60	619.45	3761.80	2012.89	1877.63	1044.88	703.73	

UAL DISCHARGE

HL - 05

M^3/S

MAX
MEAN
MIN

145.00

0.00

17.05.1991

DATE

09.01.1991

DATE

31.01.1991

OFF VOLUME IN 10^6M^3

YEARLY TOTAL

	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
04	0.003	0.008			0.054			0.145		0.961	0.004

WATER-DISCHARGE
IN M^3/S

1992

STATION: AGO ADULOJU

RIVER: OGBESE

ATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	0.80	0.20		0.22	0.35	4.80	0.35	52.50	145.	124	31.8	1.60
	0.82	0.20		0.00	0.02	4.30	0.01	52.50	94.1	125	43.0	1.52
	0.70	0.18		0.10	0.13	4.30	0.18	52.50	72.5	103	43.0	.45
	0.70	0.18		2.65	1.65	5.00	3.72	52.60	66.0	133	43.0	1.45
	0.61	0.17		1.65	1.65	5.00	2.10	105.0	58.4	133	37.8	1.30
	0.57	0.15		4.95	5.00	6.00	4.30	95.00	48.0	133	36.0	1.30
	0.53	0.14		2.32	4.50	5.46	2.65	79.50	87.0	129	33.0	1.30
	0.53	0.13		2.90	3.72	5.46	2.10	79.50	65.0	111	29.0	1.05
	0.47	0.22		4.10	4.10	6.20	2.65	75.00	63.3	111	25.5	0.80
	0.47	0.20		1.05	2.00	7.35		72.50	57.0	103	24.5	0.69
	0.47	0.18		1.60	1.60	8.50	1.65	72.50	48.9	133	23.7	0.61
	0.47	0.18		1.65	1.65	8.50	1.05	41.50	95.4	114	17.5	1.18
	0.47	0.14		2.00	1.60	9.00	1.30	46.00	30.5	111	16.0	1.05
	0.47	0.12		1.65	1.60	9.23	1.65	44.60	57.7	111	15.5	0.94
	0.47	0.12		0.94	0.94	8.65	2.63	54.10	66.0	145	14.3	0.94
	0.47	0.10		2.10	2.10	5.46	3.12	54.10	37.8	145	11.4	0.86
	0.47	0.07		2.65	2.65	4.80	3.85	37.85	37.8	145	10.5	0.70
	0.47	0.06		2.32	2.32	4.80	0.02	37.85	57.0	133	10.0	0.70
	0.47	0.06		2.80	5.00	4.96	0.00	43.00	79.0	126	8.0	0.70
	0.44	0.06		1.13	4.20	4.88	0.20	43.00	126.	114	8.5	0.51
	0.44	0.06		0.69	4.20	3.72	1.00	39.00	113	118	6.50	0.44
	0.44	0.06		0.31	4.50	4.88	0.75	39.00	77.5	133	6.00	0.35
	0.44	0.05		0.20	4.50	4.80	0.20	19.40	59.9	133	5.00	0.34
	0.44	0.05		0.15	4.80	5.00	5.47	19.40	48.9	133	5.00	0.34
	0.38	0.02		0.31	5.00	4.50	0.61	39.30	95.0	133	4.8	0.34
	0.31	0.02		0.12	5.00	4.50	1.35	37.83	95.0	139	4.30	0.61
	0.28	0.02		0.31	7.00	5.35	0.41	33.00	75.8	125	3.72	0.61
	0.28	0.02		0.31	5.35	8.50	0.31	135.0	72.0	111	3.72	0.61
	0.26	0.02		0.64	4.95	8.50	0.17	145.0	72.0	107	2.90	0.53
	0.22			0.64	4.80	8.25	0.12	129.0	57.0	95	1.30	0.53
	0.20				4.80		0.20	125.0		39.3		0.53
UM	14.56	3.18	0.64	41.58	101.7	180.7	47.22	1957	2098	3757	526.8	27.68

NNUAL DISCHARGE

							h			
AX.	145.00	h	29	08	1992			29	08	1992
EAN			DAY	MOUNTH	YEAR		h	DAY	MOUNTH	YEAR
IN	0.00	TIME	02	07	1992		TIME			

N	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
00	0.003	-	0.004	0.009	0.016		0.169	0.180	0.325	0.046	0.002

WATER-DISCHARGE
IN M^3/S

1993

STATION: AGO ADULOJU
RIVER: OGBESE

ATE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	1.25	0.26	0.24	0.28	1.05	0.51	1.65	3.72	31.0	26.60		
	1.22	0.26	0.24	0.28	1.11	0.51	1.05	5.00	33.0	19.00		
	1.18	0.31	0.31	0.28	1.22	0.51	2.10	5.00	25.5	4.95		
	1.11	0.31	0.32	0.44	1.25	1.30	4.30	5.00	27.5	4.95		
	1.05	0.31	0.32	1.05	0.08	2.65	2.65	17.00	27.0	14.30		
	1.00	0.28	0.38	1.05	0.77	2.10	3.12	10.00	25.8	14.30		
	1.00	0.26	0.38	0.80	0.61	1.05	3.24	11.40	23.0	12.60		
	0.94	0.24	0.41	0.61	0.60	1.30	3.36	14.30	23.7	10.34		
	0.94	0.22	0.47	0.75	0.80	1.65	3.60	21.00	21.0	16.00		
0	0.90	0.22	0.47	0.75	1.05	1.52	3.72	31.00	19.0	21.00		
1	0.90	0.20	0.53	0.75	1.00	1.60	4.00	43.00	20.0	23.00		
2	0.95	0.20	0.53	0.90	1.00	1.60	4.20	5.00	25.5	15.50		
3	0.26	0.20	0.53	1.00	0.61	1.65	4.80	8.75	15.5	14.30		
4	0.75	0.31	0.57	0.31	0.61	1.65	2.65	10.00	15.7	14.30		
5	0.76	0.05	0.57	0.31	0.62	1.08	2.96	14.30	15.9	13.80		
6	0.70	0.57	0.61	0.31	1.52	1.90	3.32	21.00	16.5	17.00		
7	0.69	0.02	0.61	0.31	1.18	2.10	3.48	21.00	12.3	10.00		
8	0.61	0.13	0.61	0.44	0.18	2.32	1.65	21.00	12.8	31.00		
9	0.57	1.05	0.64	0.47	0.18	2.30	1.80	43.00	13.8	28.00		
0	0.51	0.90	0.64	0.87	0.22	1.05	1.90	5.00	8.75	38.70		
1	0.44	1.05	1.00	1.05	0.25	1.60	2.10	8.75	10.0	6.50		
2	0.44	0.69	1.00	1.30	0.30	1.65	2.00	10.00	10.6	31.00		
3	0.41	0.68	0.35	1.52	1.52	2.65	2.32	11.40	6.50	25.50		
4	0.32	0.70	0.31	0.61	1.05	2.30	2.37	15.70	6.20	23.00		
5	0.31	0.75	0.31	0.80	0.51	2.10	2.40	23.00	5.90	17.00		
6	0.31	0.90	0.28	0.90	0.53	2.00	1.05	28.00	5.68	17.00		
7	0.31	1.00	0.28	1.05	0.53	1.90	1.05	21.00	11.4	16.00		
8	0.31	0.80	0.28	2.10	0.57	1.80	1.00	43.00	31.0	14.30		
9	0.28		0.28	3.85	0.61	1.70	1.00	43.00	33.0	11.40		
0	0.28		0.28	2.65	0.61	1.70	1.00	43.00	39.3	11.40		
1	0.26		0.28		0.57		1.00	43.00		10.00		
IAX	1.25	1.05	1.00	3.95	1.52	2.65	4.3	43.00	39.3	38.7		
IEAN	0.67	0.49	0.45	0.92	0.88	1.69	2.47	20.49	18.9	16.71		
IIN	0.26	0.02	0.24	0.28	0.53	0.51	1.00	3.72	5.68	4.95		
UM	20.97	13.88	14.0	27.7	27.37	50.6	76.64	635.3	567.8	518.24		

ANNUAL DISCHARGE

HL - 05

M^3/S

MAX
MEAN
MIN

DATE

DATE

RUNOFF VOLUME 10^9M^3

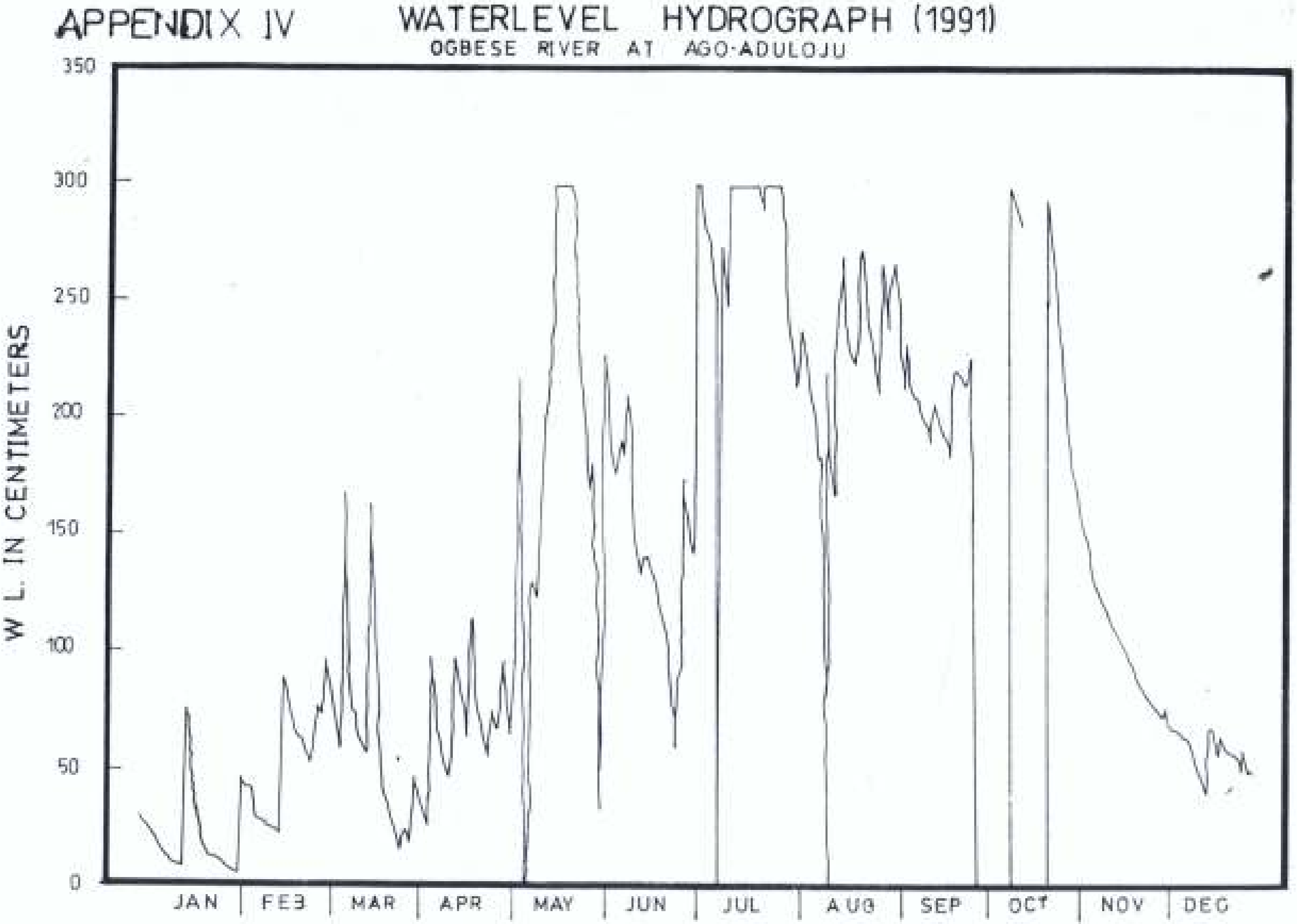
1993

YEARLY TOTAL

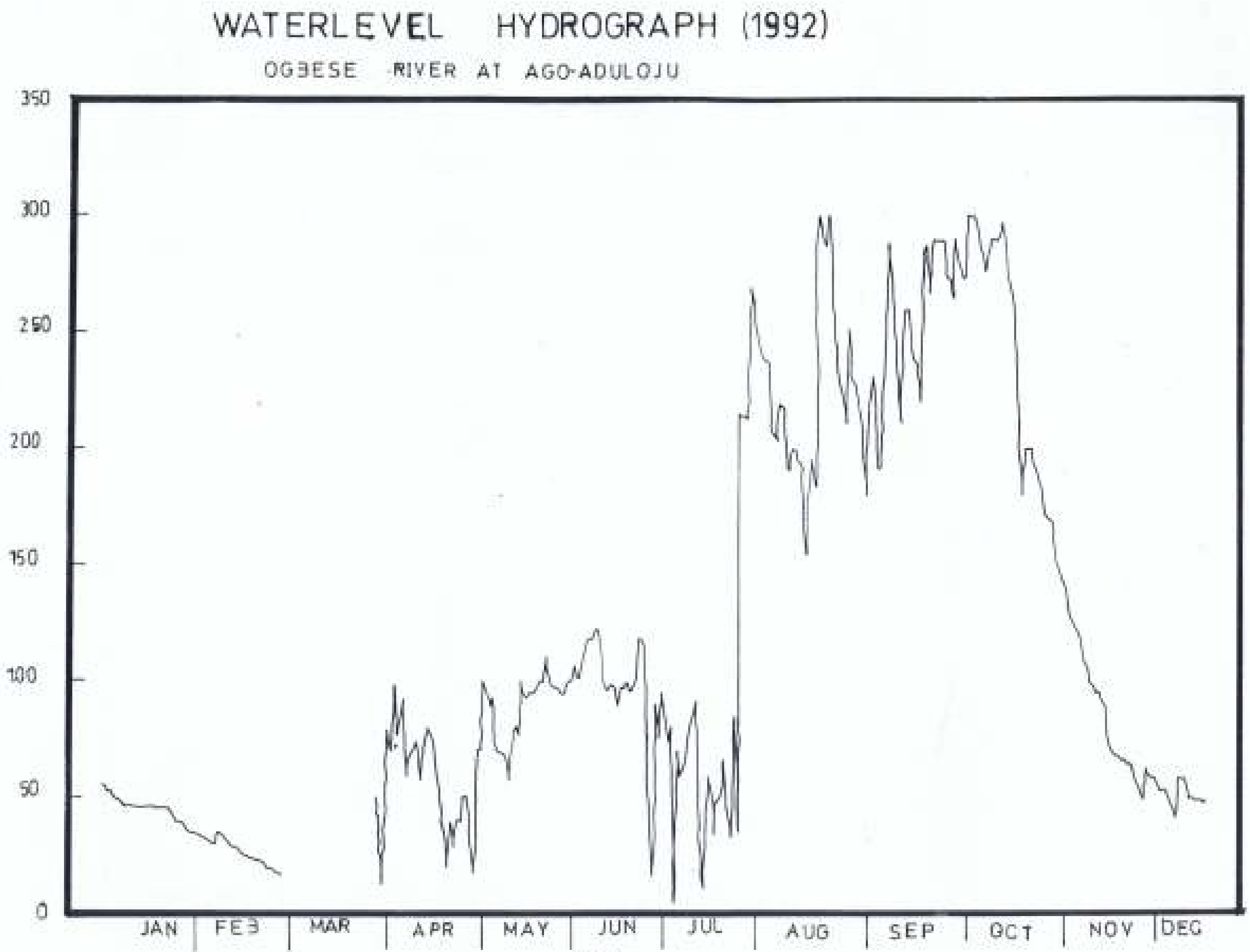
YEARLY TOTAL

JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.055	0.049	0.048		

APPENDIX IV

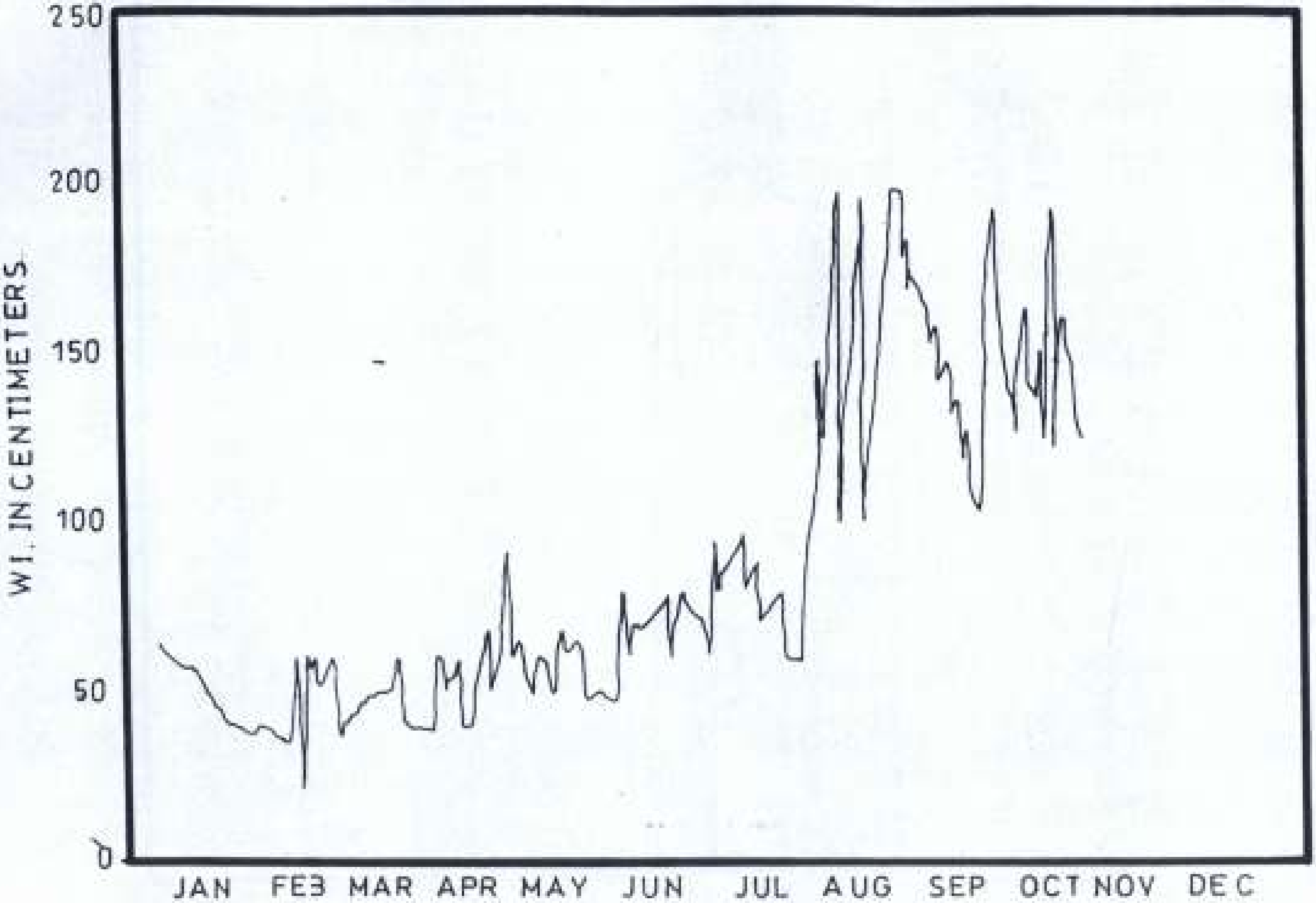


WATERLEVEL HYDROGRAPH (1991)
OGBESE RIVER AT AGO-ADULOJU
W L. IN CENTIMETERS
350
300
250
200
150
100
50
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC


WATERLEVEL HYDROGRAPH (1992)
OGBESE RIVER AT AGO-ADULOJU
350
300
250
200
150
100
50
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

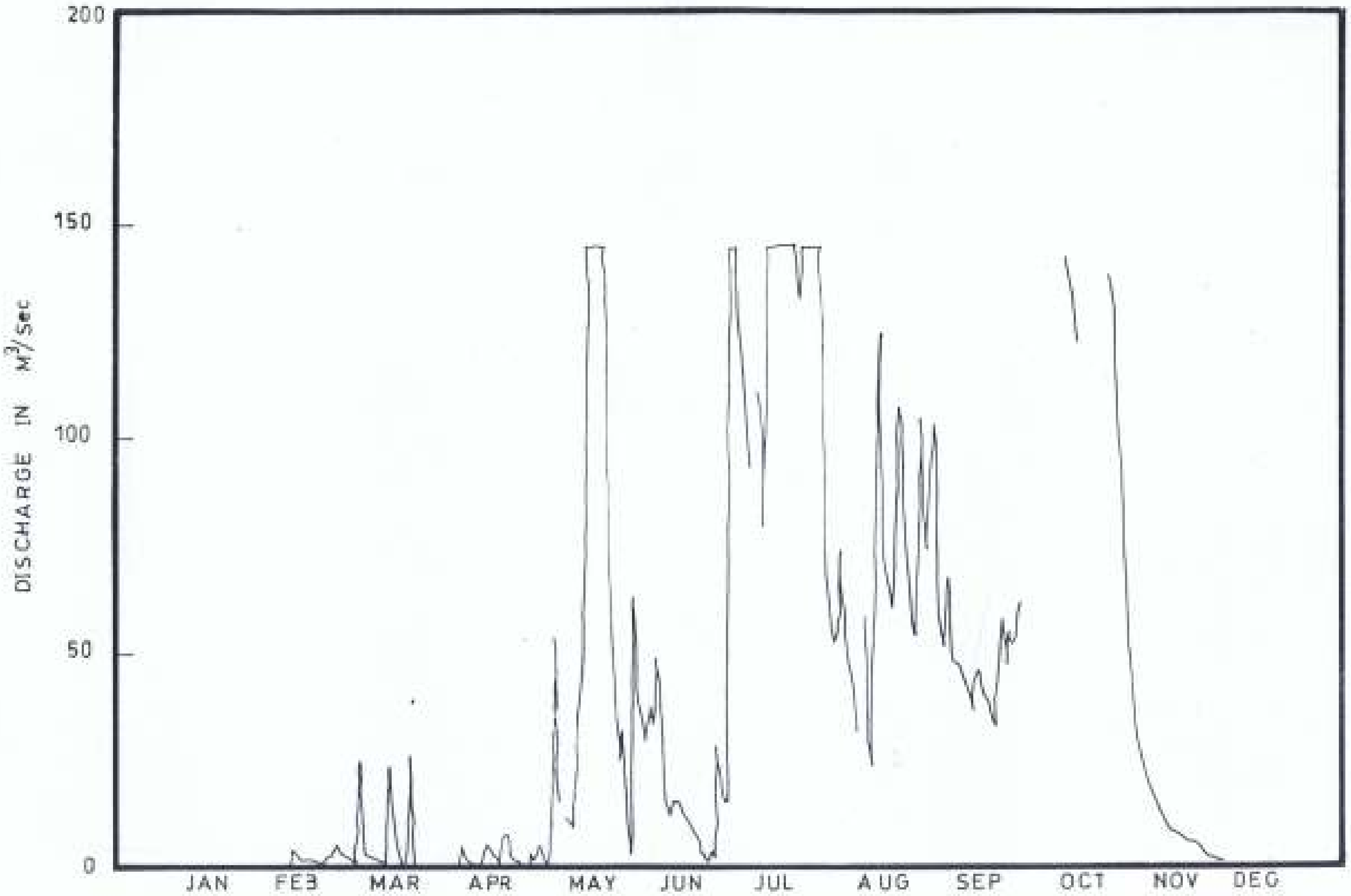
WATERLEVEL HYDROGRAPH (1993)

OGBESE RIVER AT AGO-ADULOJU



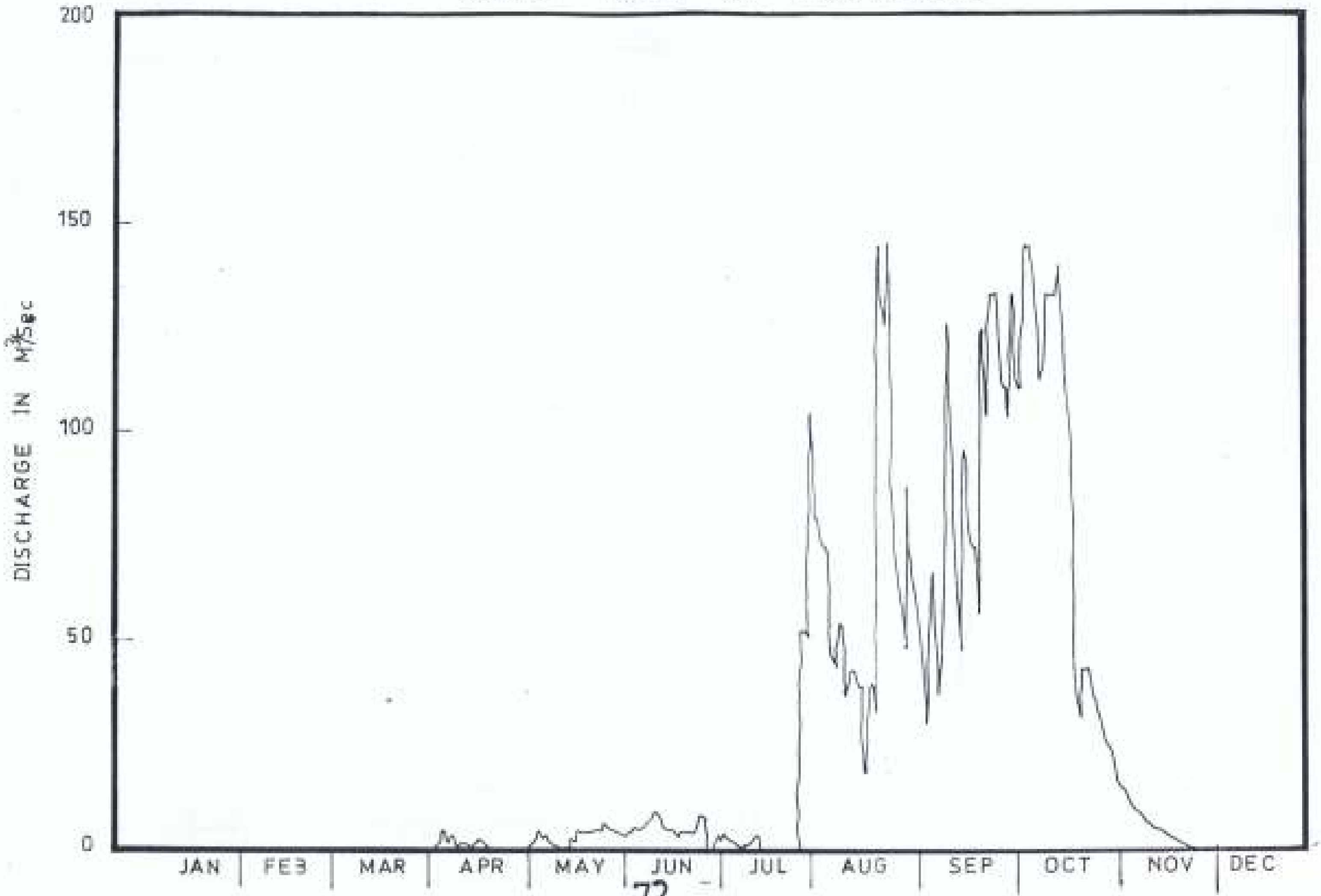
WATER DISCHARGE HYDROGRAPH (1991)

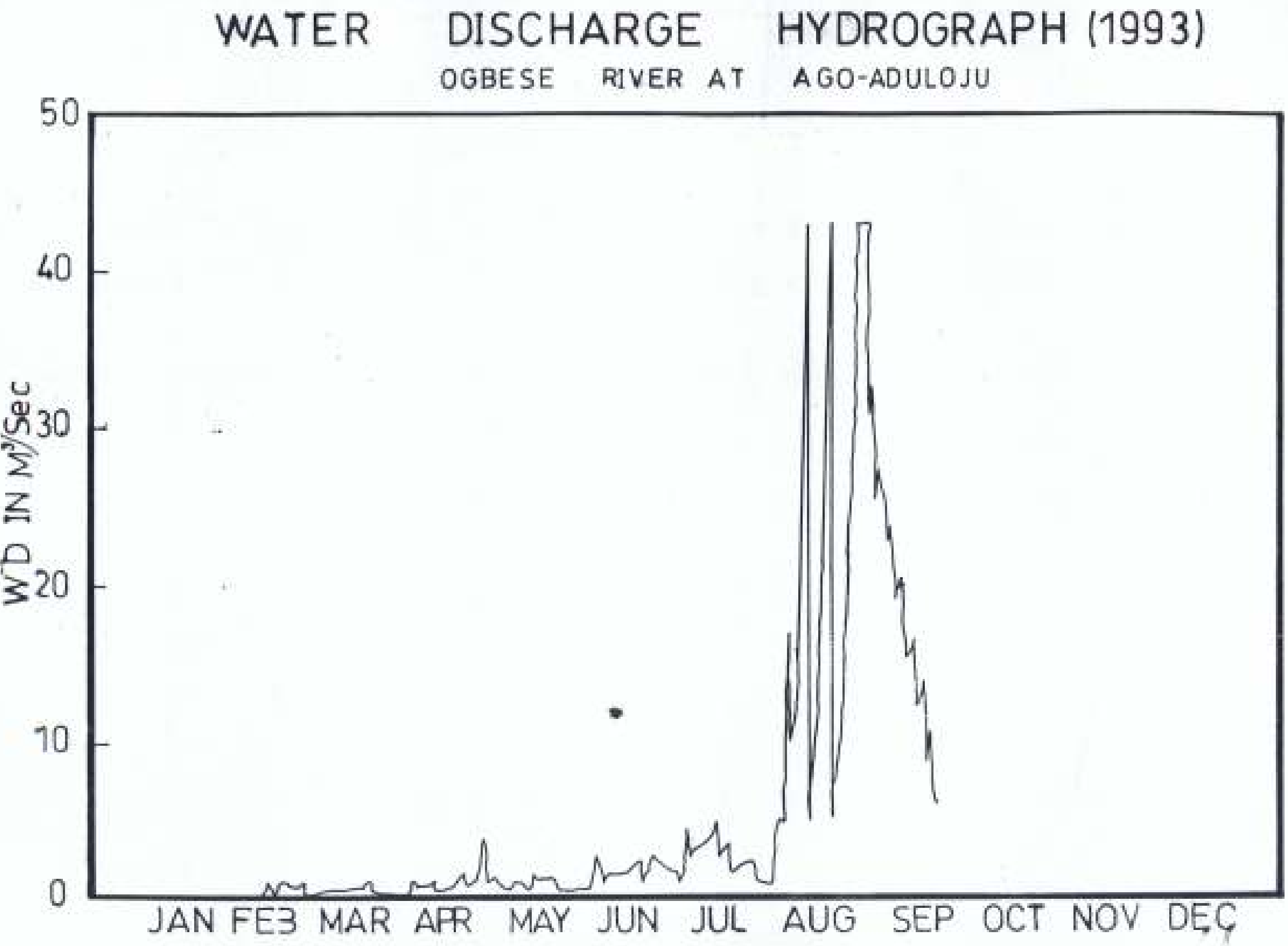
OGBESE RIVER AT AGO-ADULOJU

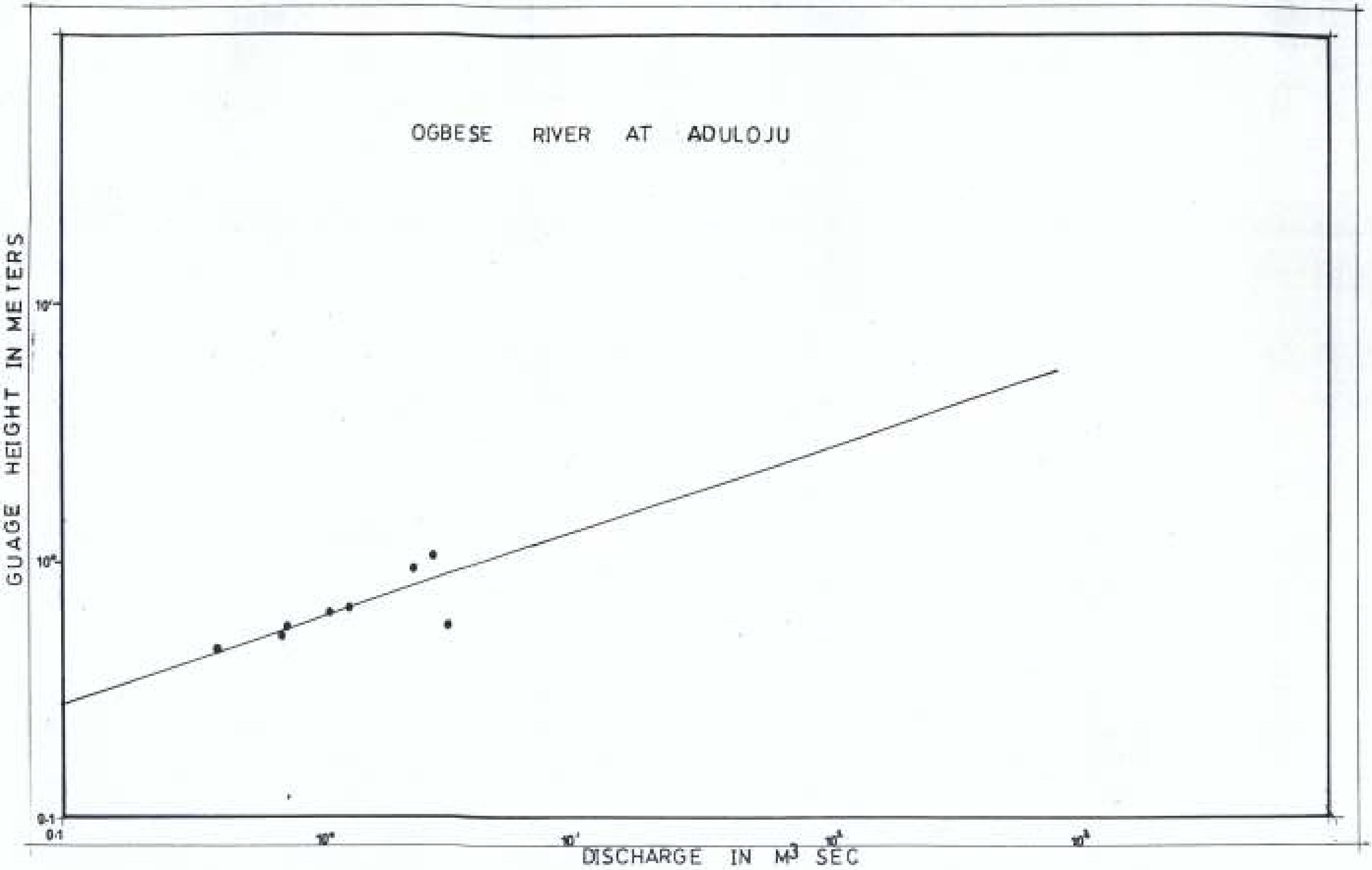


WATER DISCHARGE HYDROGRAPH (1992)

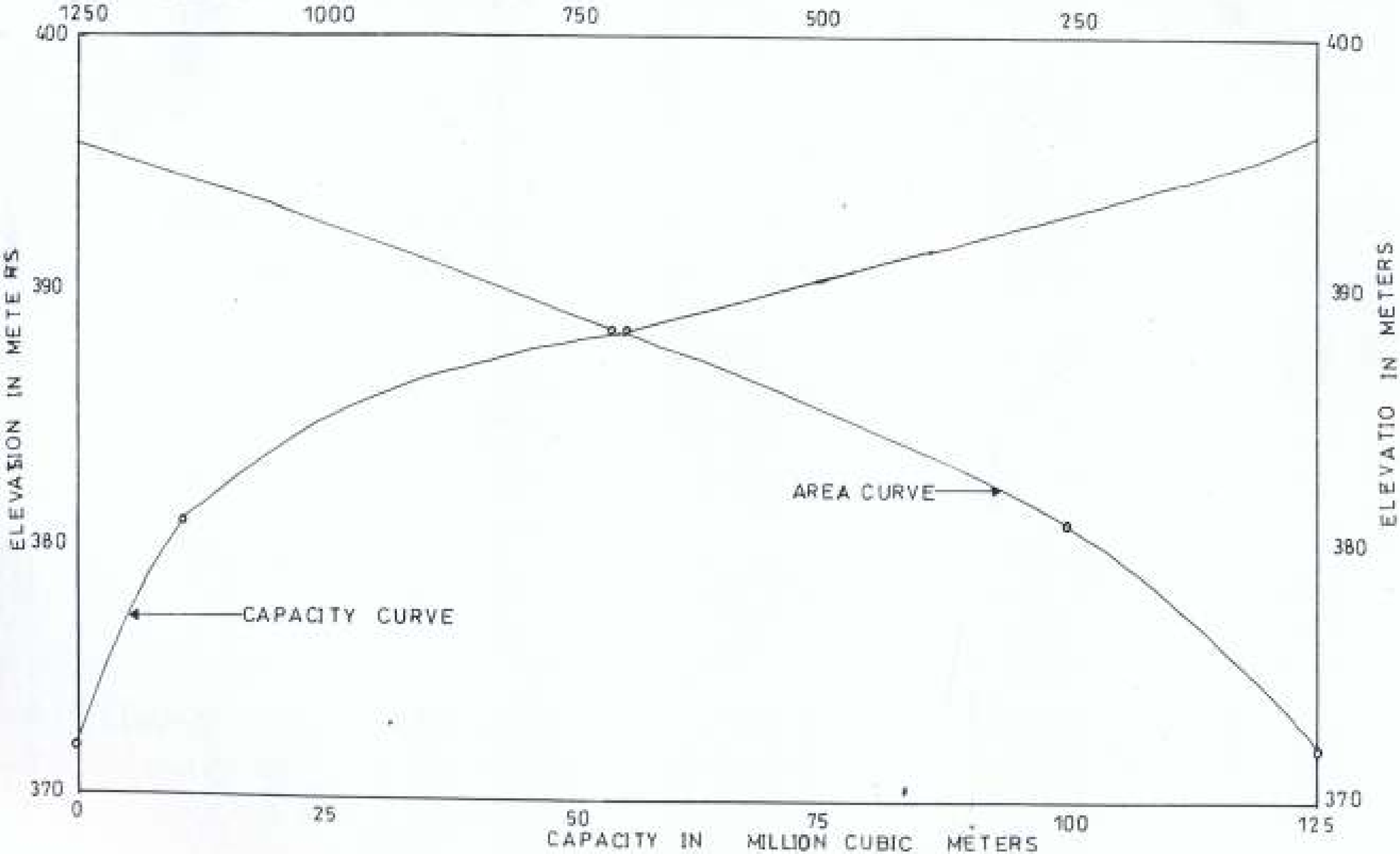
OGBESE RIVER AT AGO-ADULOJU

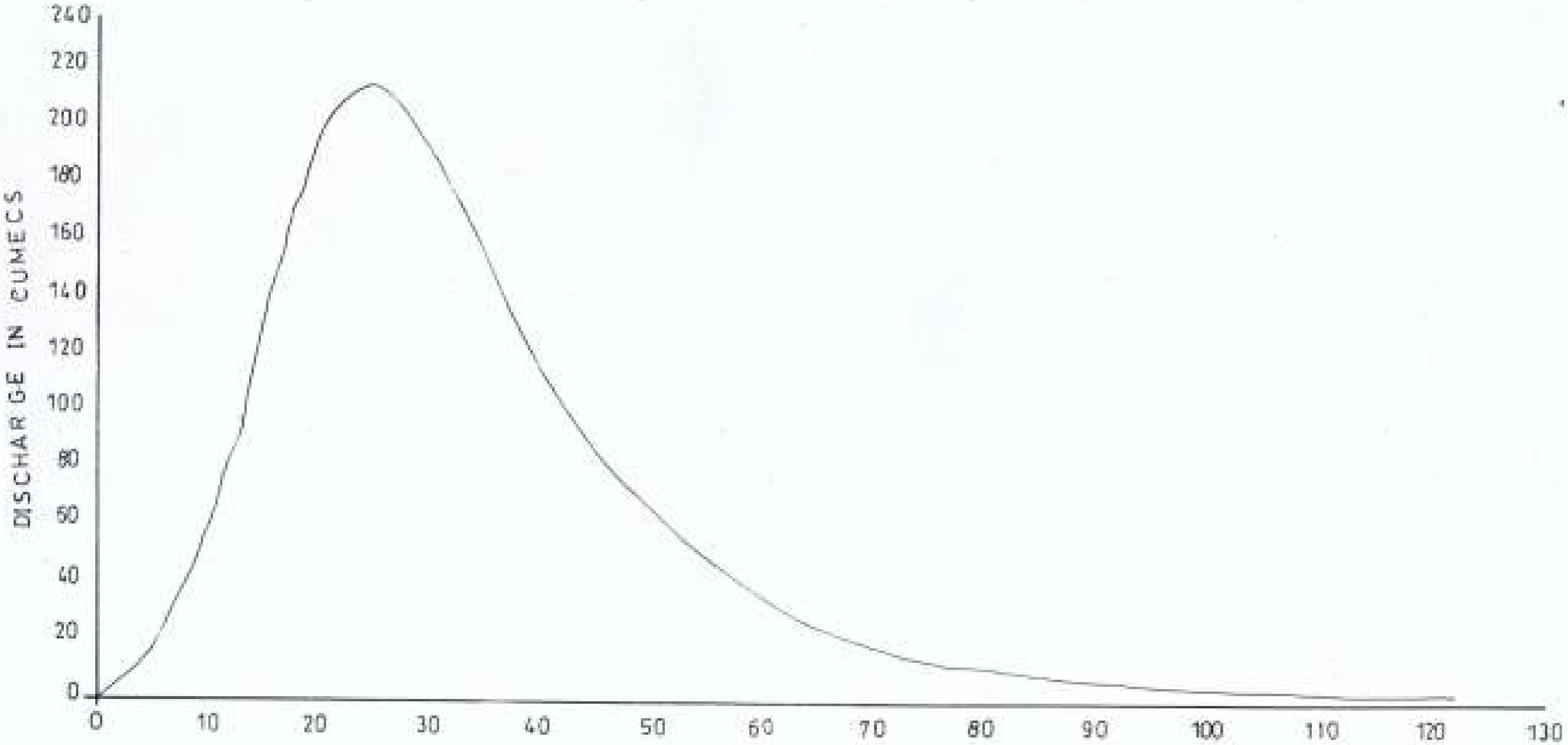



WATER DISCHARGE HYDROGRAPH (1993)
OGBESE RIVER AT AGO-ADULOJU
W.D IN M³/Sec
50
40
30
20
10
0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC


OGBESE RIVER AT ADULOJU
GUAGE HEIGHT IN METERS
DISCHARGE IN M3 SEC
0·1
0·1

APPENDIX VI


1250
1000
750
500
250
400
390
380
370
ELEVASION IN METERS
ELEVATIO IN METERS
AREA CURVE
CAPACITY CURVE
0
25
50
75
100
125
CAPACITY IN MILLION CUBIC METERS



APPENDIX VII FLOOD HYDROGRAPH FOR OGBESE AT ADULOJU